SEPTEMBER 1977 VOLUME 2, Number 9 $2.00 in USA

BYTE

the small systems journal

ALTAIR 8800
VECTOR 1
OSI CHALLENGER
6800 COMPUTER SYSTEM
IMSAI 8080
MINI-COM
ROBERT
'77 TINNEY

SWTPC announces first dual minifloppy kit under $1,000

MINIFLOPPY DISK SYSTEM

Now SWTPC offers complete best-buy computer system with $995 dual minifloppy, $500 video terminal/monitor, $395 4K computer.

SWTPC MINIFLOPPY DISK SYSTEM

$995 MF-68 Dual Minifloppy
You need dual drives to get full benefits from a minifloppy. So we waited to offer a floppy until we could give you a dependable dual system at the right price.

The MF-68 is a complete top-quality minifloppy for your SWTPC Computer. The kit has controller, chassis, cover, power supply, cables, assembly instructions, two highly reliable Shugart drives, and a diskette with the Floppy Disk Operating System (FDOS) and disk BASIC. (A floppy is no better than its operating system, and the MF-68 has one of the best available.) An optional $850 MF-6X kit expands the system to four drives.

Circle 200 on inquiry card.

CT-64 TERMINAL SYSTEM

$500 Terminal/Monitor
The CT-64 terminal kit offers these premium features: 64-character lines, upper/lower case letters, switchable control character printing, word highlighting, full cursor control, 110-1200 Baud serial interface, and many others. Separately the CT-64 is $325, the 12 MHz CT-VM monitor $175.

SWTPC 6800 COMPUTER SYSTEM

$395 4K 6800 Computer
The SWTPC 6800 comes complete with 4K memory, serial interface, power supply, chassis, famous Motorola MIKBUG® mini-operating system in read-only memory (ROM), and the most complete documentation with any computer kit. Our growing software library includes 4K and 8K BASIC (cassettes $4.95 and $9.95; paper tape $10.00 and $20.00). Extra memory, $100/4K or $250/8K.

Other SWTPC peripherals include $250 PR-40 Alphanumeric Line Printer (40 characters/line, 5 x 7 dot matrix, 75 line/minute speed, compatible with our 6800 computer and MITS/IMSAI); $79.50 AC-30 Cassette Interface System (writes/reads Kansas City standard tapes, controls two recorders, usable with other computers); and other peripherals now and to come.

Enclosed is:

_____ $1,990 for the full system shown above (MF-68 Minifloppy, CT-64 Terminal with CT-VM Monitor).
_____ $995 for the Dual Minifloppy
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_____ $175 for the CT-VM Monitor
_____ $395 for the 4K 6800 Computer
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_____ $79.50 for AC-30 Cassette Inferface
_____ Additional 4K memory boards at $100
_____ Additional 8K memory boards at $250
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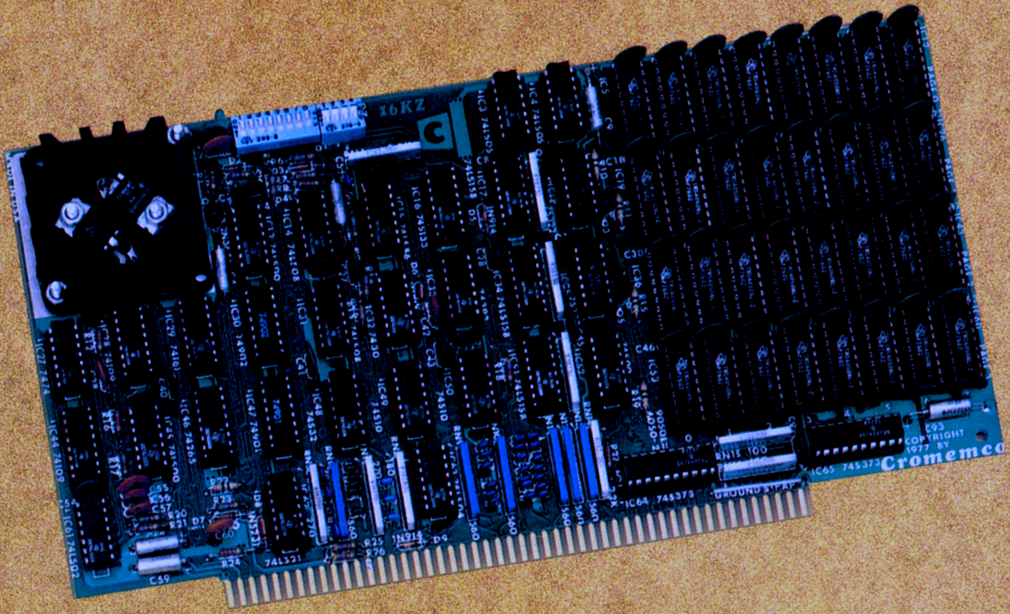
16KZ
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The new 16K RAM card that turns your computer into a working giant

Available now — store/factory

Here's the industry's leading 16K RAM card.

It has two outstanding features that make it important to you:

(1) It's fast: It operates up to 4 MHz **with no wait states.** That's important because it lets you run programs on your Cromemco Z-1 and Z-2 computers in about half the time required by other systems. Even if your present computer is not 4 MHz fast, this new Model 16KZ RAM equips you for the time when you'll need and want higher computer speed.

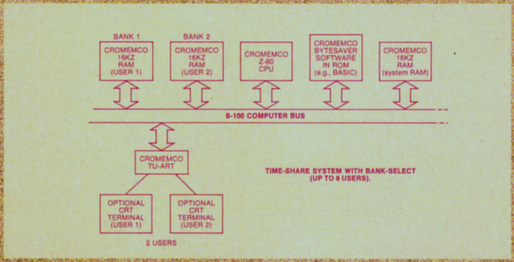
(2) **It has Cromemco's Bank-Select feature.** Bank-Select lets you expand memory far beyond 64K bytes. Not **just beyond** 64K but **far beyond — up to 512K** bytes if you wish. Again, with Cromemco you get present outstanding performance plus obsolescence protection.

Bank-Select lets you organize memory into 8 banks of 64K each. The active bank is software-selected.

A useful giant

Whatever your S-100 bus computer — Cromemco, Altair 8800 or IMSAI 8080 — you can have enormous memory with the new Model 16KZ. You can run the large programs and files that make computers truly valuable — that take them out of the toy class and make them useful, producing units.

With Bank-Select you can even operate an S-100 bus computer as a time-share computer with up to 8 stations. A given memory bank can be accessed only by one station, so there is full confidentiality.


BANK 1
CROMEMCO 16KZ RAM (USER 1)
BANK 2
CROMEMCO 16KZ RAM (USER 2)
CROMEMCO Z-80 CPU
CROMEMCO BYTESAVER SOFTWARE IN ROM (e.g., BASIC)
CROMEMCO 16KZ RAM (system RAM)
S-100 COMPUTER BUS
CROMEMCO TU-ART
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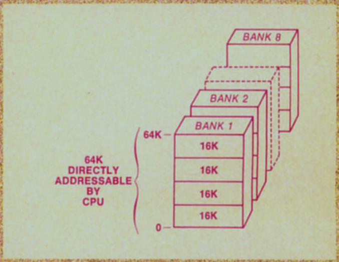
OPTIONAL CRT TERMINAL (USER 2)
2 USERS

TIME-SHARE SYSTEM WITH BANK-SELECT (UP TO 8 USERS).


BANK 8
BANK 2
BANK 1
64K
16K
16K
16K
16K
0
64K DIRECTLY ADDRESSABLE BY CPU

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16K RAM memory kit (Model 16KZ-K) . . . . $495.

16K RAM memory assembled, tested, and burned in for 160 hours (Model 16KZ-W) . . . . $795.

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Circle 201 on inquiry card.

Meet the most powerful μC system available for dedicated work. Yet it's only $595.*

Here's the muscle you've been telling us you wanted: a powerful Cromemco microcomputer in a style and price range ideal for your dedicated computer jobs—ideal for industrial, business, instrumentation and similar applications.

It's the new Cromemco Z-2 Computer System. Here's some of what you get in the Z-2 for only $595:

- The industry's fastest μP board (Cromemco's highly regarded 4 MHz, 250-nanosecond cycle time board).
- The power and convenience of the well-known Z-80 μP.
- A power supply you won't believe (+8V @ 30A, +18V and −18V @ 15A — ample power for additional peripherals such as floppy disk drives).
- A full-length *shielded* motherboard with 21 card slots.
- Power-on-jump circuitry to begin automatic program execution when power is turned on.
- S-100 bus.
- Standard rack-mount style construction.
- All-metal chassis and dust case.
- 110- or 220-volt operation.

DEDICATED APPLICATIONS

The new Z-2 is specifically designed as a powerful but economical dedicated computer for systems work. Notice that the front panel is entirely free of controls or switches of any kind. That makes the Z-2 virtually tamper-proof. No accidental program changes or surprise memory erasures.

FASTEST, MOST POWERFUL μC

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Since the Z-2 uses the Z-80, your present 8080 software can be used with the Z-2. Also, Cromemco offers broad software support including a monitor, assembler, and a BASIC interpreter.

The Z-2 uses the S-100 bus which is supported by the peripherals of dozens of manufacturers. Naturally, all Cromemco peripherals such as our 7-channel A/D and D/A converter, our well-known BYTESAVER with its built-in PROM programmer, our color graphics interface, etc., will also plug into the S-100 bus.

LOW, LOW PRICE

You'll be impressed with the Z-2's low price, technical excellence and quality. So see it right away at your computer store—or order directly from the factory.

Z-2 COMPUTER SYSTEM KIT (MODEL Z-2K) (includes 4 MHz μP card, full-length 21-card-slot motherboard, power supply, one card socket and card-guide set, and front panel; for rack mounting) . . . .$595.

Z-2 COMPUTER SYSTEM ASSEMBLED (MODEL Z-2W) (includes the above as well as all 21 sockets and card guides and a cooling fan; for rack mounting) . . . $995.

Z-2
Computer System
Cromemco

Shown with optional bench cabinet

***kit price**

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About the Cover

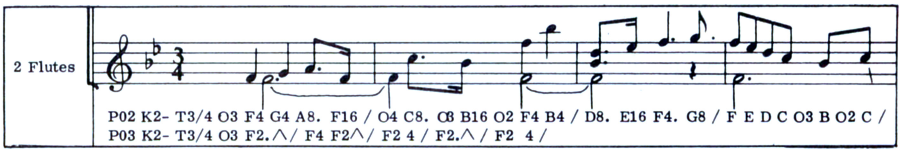
The conceptual target of the cover painting for September was a theme of music and sound. Taking this theme, Robert Tinney implemented this cover, entitled "Breaking the Sound Barrier." It was inspired by the legend of opera star Enrico Caruso breaking a wine glass through sympathetic resonances with his voice. The sound barrier we're referring to, of course, is the physical barrier between a program and the real world, which is crossed by one of a number of musical and audio output devices and software presently on the market or about to come to the marketplace.

In This BYTE

Experimenting with music on your computer can be very rewarding. If you're looking for a streamlined way to input musical material into your system, look no further. Hal Taylor shows you how in **SCORTOS: Implementation of a Music Language.** Who knows, with SCORTOS you could have your synthesized concerto for alpenhorn and orchestra up, running and debugged by next week.

A naked microcomputer board is unprotected from a harsh environment. In his article this month, R Travis Atkins turns couturier as he fashions external garb in the form of **A New Dress for KIM.**

Steve Ciarcia returns this month with a combjnation of tutorial ideas and practical details so characteristic of his style. Read Steve's **Control the World! (Or at Least a Few Analog Points)** to review digital to analog conversion, and learn how BASIC can be used to compute and represent waveforms through a converter using a scope as a display.



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P02 K2- T3/4 O3 F4 G4 A8. F16 / O4 C8. C8 B16 O2 F4 B4 / D8. E16 F4. G8 / F E D C O3 B O2 C /
P03 K2- T3/4 O3 F2.^/ F4 F2^/ F2 4 / F2.^ / F2  4 /
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A Tiny Assembler need not have tiny features, as Jack Emmerichs explains in his article on **Expanding the Tiny Assembler.** Jack adds structured programming features and incremental improvements to the Tiny Assembler design he described in April and May issues of BYTE this year. By reorganizing the symbol table to add the "begin" pseudo operation, "Tiny" takes on a number of "big" features while preserving practical operation as Version 3.1 in under 4 K bytes of memory.

Looking for a very simple way to build a wire wrap board? Ira Rampil has an idea in **A One-Sided View of Wire Wrap Sockets.**

Are you interested in making music with your computer? Hal Chamberlin's **A Sampling of Techniques for Computer Performance of Music** is one of the best ways to get acquainted with this fascinating field. The article will give you complete directions for creating 4 part harmony on your microprocessor for a very modest investment. Get out those 4 voice fugues that have been languishing in your music drawer and bring them to life!

Did you ever want your computer to sing you a lullaby? Well, as Ted Sierad points out, it's not too hard to do so if you **Tune In With Some Chips,** using the circuit and software he describes.

The roster of "complete" computer systems for the amateur computing person expanded considerably with the introduction of the Noval 760. Turn to an account by designers Lane T Hauck and James D Nash, **System Description: the Noval 760,** for details of the philosophy and overall design behind this product.

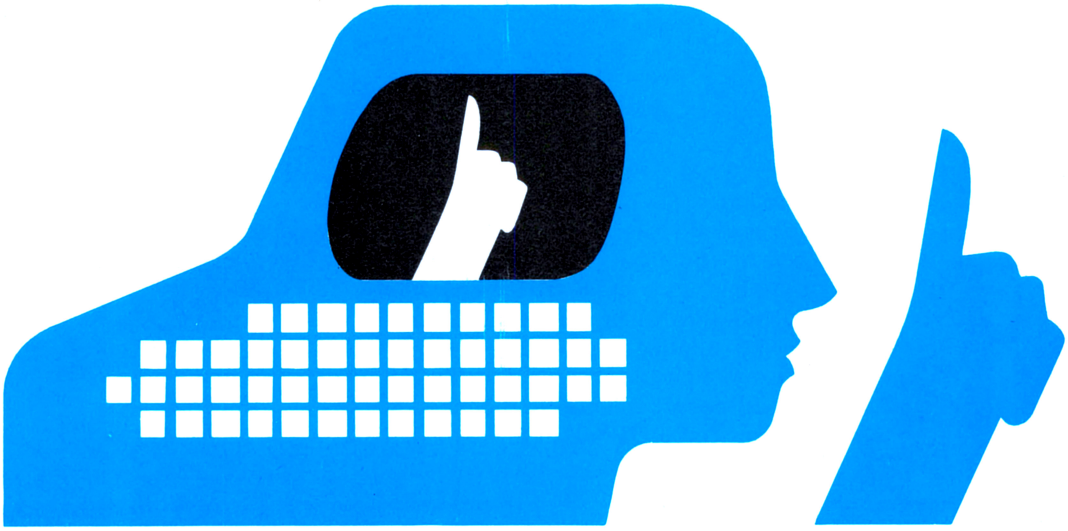
A double feature written by Carl Helmers and Chris Morgan of BYTE covers key details of an interesting musically oriented peripheral which can be added to the personal computer: acoustic pianos with pneumatic player actions. **Notes on Anatomy: The Piano's Reproductive System** gives global morphology of a Duo-Art upright reproducing piano. **Notes on Interfacing Pneumatic Player Pianos** covers some details of how to engineer a computer interface for the pneumatic control lines using valve elements manufactured for the pipe organ industry.

With this issue, readers will note the continued progression of information on APL, and several articles introducing the theme of music representation and performance with computers. Readers can look forward to further information on these themes in future issues.

APL is one of the most interesting high level languages around these days. If you want to continue learning what goes on in an APL interpreter, read part 2 of Mike Wimble's **An APL Interpreter for Microcomputers.** Here Mike covers the expression evaluation sections of the interpreter.

Many people are familiar with use of orthogonal basis functions such as sines and cosines to compute arbitrary waveforms. But how many readers have heard of **Walsh Functions: A Digital Fourier Series** which forms arbitrary repetitive waveforms as weighted sums of digital waveforms? Read Benjamin F Jacoby's tutorial to find out a bit about these functions and their generation.

Announcing the West Coast's largest Personal Computing Show. April 28, 29, and 30, 1978 at California's brand new Long Beach Convention Center. This is a selling show with 180 booths (each draped, carpeted and with 500 watts of electricity). Three full days of conference sessions. There will be home brew exhibits, exhibitors lounge, inquiry badge system, computerized registration, a newsroom, and a full blown advertising and promotional campaign to bring you thousands of qualified buyers.



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Editorial

BYTE's 0.02 Centennial

Reflections on Entry into Our Third Year

By Carl Helmers

The September 1977 BYTE marks the end of the second year of our publication's existence in the public eye, although actual work on the magazine began at the end of May 1975. Since that time, the phenomenon of personal computing has expanded considerably as more people become aware of it through mass media publications, radio and television shows, trade fairs such as the First West Coast Computer Faire and the National Computer Conference. Good sense says a peak must be reached in any new and expanding marketplace, but to date we have seen no signs of the traditional "shakeout" (intense competition such as that which occurred recently in the calculator and watch marketplaces). For whatever reasons, a few firms have fallen by the wayside, but the general trend still remains one of expansion and exploration, to the ultimate benefit of the user of personal computing products who is presented with new options and lower prices for older options.

The "appliance" computer, a complete system presented in an assembled and tested package is on the threshold of its ultimate dominance in the general purpose personal computer field: from the high end, moving down in price, we find products like the Apple-II and the Commodore PET 2001 machines; from the low end, moving up in function at the same price, we find the increasing versatility and capability of programmable calculators such as the newly announced Texas Instruments SR-59 with its optional ROM software modules and expanded printing and magnetic card peripheral capabilities. And for the discrimi-

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Articles Policy

BYTE is continually seeking quality manuscripts written by individuals who are applying personal systems, or who have knowledge which will prove useful to our readers. Manuscripts should have double spaced typewritten texts with wide margins. Numbering sequences should be maintained separately for figures, tables, photos and listings. Figures and tables should be provided on separate sheets of paper. Photos of technical subjects should be taken with uniform lighting, sharp focus and should be supplied in the form of clear glossy black and white or color prints (if you do not have access to quality photography, items to be photographed can be shipped to us in many cases). Computer listings should be supplied using the darkest ribbons possible on new (not recycled) blank white computer forms or bond paper. Where possible, we would like authors to supply a short statement about their background and experience.

Articles which are accepted are typically acknowledged with a binder check 4 to 8 weeks after receipt. Honorariums for articles are based upon the technical quality and suitability for BYTE's readership and are typically $25 to $50 per typeset magazine page. We recommend that authors record their name and address information redundantly on materials submitted, and that a return envelope with postage be supplied in the event the article is not accepted.■

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Letters

REGARDING INTERFACING THE IBM SELECTRIC KEYBOARD PRINTER

My congratulations to Mr Fylstra on a job well done in his June article in BYTE. I spent half a year, back in 1970, on designing the interface for the 735 Selectric to the Microdata 800 Minicomputer, and in the process went through many of the discoveries revealed in the article. As the man who serviced our IBM IO printers (an ex-IBMer) said to me, that machine is a triumph of development over engineering!

One fruit of my work was a 2048 bit ROM which we custom programmed to do the ASCII to "bail code" conversion and back, without recourse to a software lookup table. It is still available as the MM5230KP from National Semiconductor. But note that it handles only the "correspondence" version of the Selectric: our machine needed full upper and lower case graphics.

Dan's comments on using the "a" and "b" contacts for figuring ready/busy of the printer are quite valid. One thing we learned was that allowing the clutch to stop between characters does lead to shortened life between adjustments. Back in 1970 we used a TTL voting circuit to read the contacts, because they bounced so much, and accurate timing is essential for "wide open" running.

One last point: The contacts are open reed, and *must* be "wetted" by using a current several times higher than the 5 mA shown, else they get dirty very quickly.

Good luck to all ye who pass this way again!

Richard Percival
National Semiconductor GmbH
Industriestrasse 10
808 Furstenfeldbruck GERMANY

IS BUS COMPATIBILITY NEEDED?

I have recently noticed that many people ascribe a certain importance to a product if it is "Altair (S-100) compatible." This should not be unusual; many people own Altair bus based systems and wish to buy only what is useful to them. But I am angered by people who automatically downgrade a product that is not S-100, even if they do not own a system themselves. They seem to think that compatibility and board interchangeability rank high on the list of priorities for a "good" computer system. This is typical of most of the hobby market.

I feel that the next few years will bring a change in that viewpoint. As computers become more and more common, processor power and built-in features will take precedence over bus compatibility. This is especially true in the consumer market. Who, in the early days of radio, would buy a separate tuner, amplifier and speaker assemblies if they could buy a complete, assembled unit? Consumers would never consider buying and inserting full size printed circuit boards into a system; they will rarely care whether they have a separate video board of a video section or a single board computer if it works.

This is not to say that the Altair (S-100) design will vanish. The large number of systems and boards available makes it a great system for *someone who knows what he or she is doing.* For all others, a system that is self-enclosed and requires no expansion for basic IO devices (tape recorder, TV set) will be more popular.

If we are to go anywhere with home computers, as designers we must understand what consumers expect them to do; we must not force them to adapt to our insufficiencies; we must learn to provide a useful and well-integrated product.

C David Espinosa
21191 Gardens Dr
Cupertino CA 95014

The first automobiles were not truly consumer oriented, either, but as the public became educated in the uses of the product and as manufacturers learned more about the product and its design, the personal transporter became today's ubiquitous mechanism. In the continuing evolution of the personal computer, a similar user orientation is in the works and presently unfolding as innovative technological entrepreneurs gain experience and refine the product concepts.

IBM 360/370 EMULATIONS

Concerning Tom Koon's letter in the May 1977 BYTE about 360/370 emulation: this has already been done in at least one instance that I know of. Roger Appel of Interdata recently mentioned that his company took on this project a few years back. Interdata's Boston area phone is (617) 890-0557, and as to the price, don't count on it being cheap.

J Howell Mitchell Jr
Dynamics Research Corp
60 Concord St
Wilmington MA 01887

A PUZZLE: DELETING THE DELIMITER

I have comments to make regarding Dave Chapman's problems with delimiting the delimiter (May 1977 BYTE). There is a similar but even more annoying problem if you're working with an editor program which has a delete character.

The question is, how do you change

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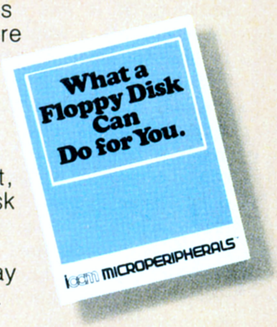

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a delete character, when typing the character deletes the previous character? A variation of this exercise is obtained when you suppose that somehow the character for "change" has been set to be the character for "delete."

These are amusing puzzles, and it can be left to the reader to figure out how to get into and out of these situations.

E G Johnston
Computer Sciences Corporation
Silver Spring MD 20910

MORE ON SR-52/SR-51 INTERNALS

I am interested in interfacing the SR-52 with some other equipment and have gathered a little (very little) information which might help William D Lewis (letters of June 1977 BYTE) with his SR-52. First, the SR-52 and SR-51 terminal strips appear to be similar. The SR-52 has a TMC0501NL which they call U1 and a TMC0524NL which appears to be a version of the TMC-0523NS-5, but it is called U2.

The terminal strip connectors in the order shown in the June BYTE are: NC, D12, 02, Ext, IDLE, IRG, D15, DO, 01, KN, KP, KR. The pinouts of the TMC-0501NL are: 1(DPT), 2(SB), 3(SA), 4(SF), 5(SC), 6(SD), 7(SE), 8(KT), 9(KS), 10(KR), 11(KQ), 12(KP),

Continued on page 174

AN IMPORTANT WARNING ABOUT THE ELEMENT MERCURY AND ITS COMPOUNDS

The June 1977 issue of BYTE arrived recently and Mr Pasken's letter on obtaining mercury caught my eye, causing me to go back and read Mr Firth's article on weather prediction in the December 1976 issue, page 62, which I had not read the first time around. I fear that Mr Firth, and perhaps Mr Pasken, are under a misapprehension as to the nature of the hazards of contact with metallic mercury. As an industrial hygienist, I feel impelled to set the record straight and to comment on Mr Pasken's method of obtaining mercury.

A note in Mr Firth's article states that "mercury can be harmful if you breath the vapors, swallow it or otherwise get it in your body. But there is little danger from . . . putting your hands in it." It is true that mercury vapors are harmful; however, the rest of the statement I have quoted is, by and large, *not true* for metallic mercury, which is what one would use in a barometer. Metallic mercury is readily absorbed through the skin. On the other hand, if swallowed it passes virtually without absorbtion through the gastrointestinal tract and presents very little hazard to the individual. (One should, of course, try to avoid swallowing it anyway.)

Mr Pasken does not address the hazards of mercury, but his method of obtaining it is one which, in view of those hazards, I would not recommend. In breaking open mercury switches and cleaning the mercury by passing it through a hole in a filter paper, one's tendency would be to work with the material rather close to the face. This could result in considerable breathing of mercury vapors. (Remember, most readers will not be doing this in a chemistry lab equipped with adequately performing fume hoods.) In addition, the potential for skin contact is obviously quite great.

Mercury, if spilled on a floor, can be quite difficult to clean up. Sweeping will only break it into smaller and smaller drops which will lodge in cracks and increase the cleaning problem. Vacuuming is a preferred method. But most people don't keep laboratory aspirators in their homes, and contaminating the family vacuum cleaner with mercury is hardly an ideal solution. There are also commercial materials which when sprinkled onto a mercury spill create mercury compounds which can be swept up, but I doubt that many people have such things available to them at home. And frankly, should mercury be spilled on a rug, I can't imagine how it could be cleaned up completely.

There are a few other points to consider. If mercury is spilled on your floor, it is a greater hazard to your small children and pets than to you. They are down there where the vapors are stronger and are in more intimate contact with the floor, and potentially with the spill. Also, mercury is fun to play with. Children, and adults too, like to coat coins with it or watch a droplet roll around the palm of a hand. Such recreation leads to skin contact, *which should be avoided.* Finally, should you be working with mercury in your home in winter, and your home is not heated with forced air, the room in which you work will not have much ventilation and the mercury vapor concentration will be higher than otherwise.

I should mention that the above statements on the hazards of mercury are made with respect to metallic, or elemental, mercury. Mercury compounds can also be hazardous in other modes of exposure.

In summary, metallic mercury is a harzardous material, both by breathing the vapors and by skin contact. If you must work with it, avoid skin contact, and, if you don't have access to a chemistry laboratory, work with it outside or in a well-ventilated room. Store mercury, and your open dish mercury barometer, where children, pets and other curious people cannot get at it, again, preferably in a well-ventilated room.

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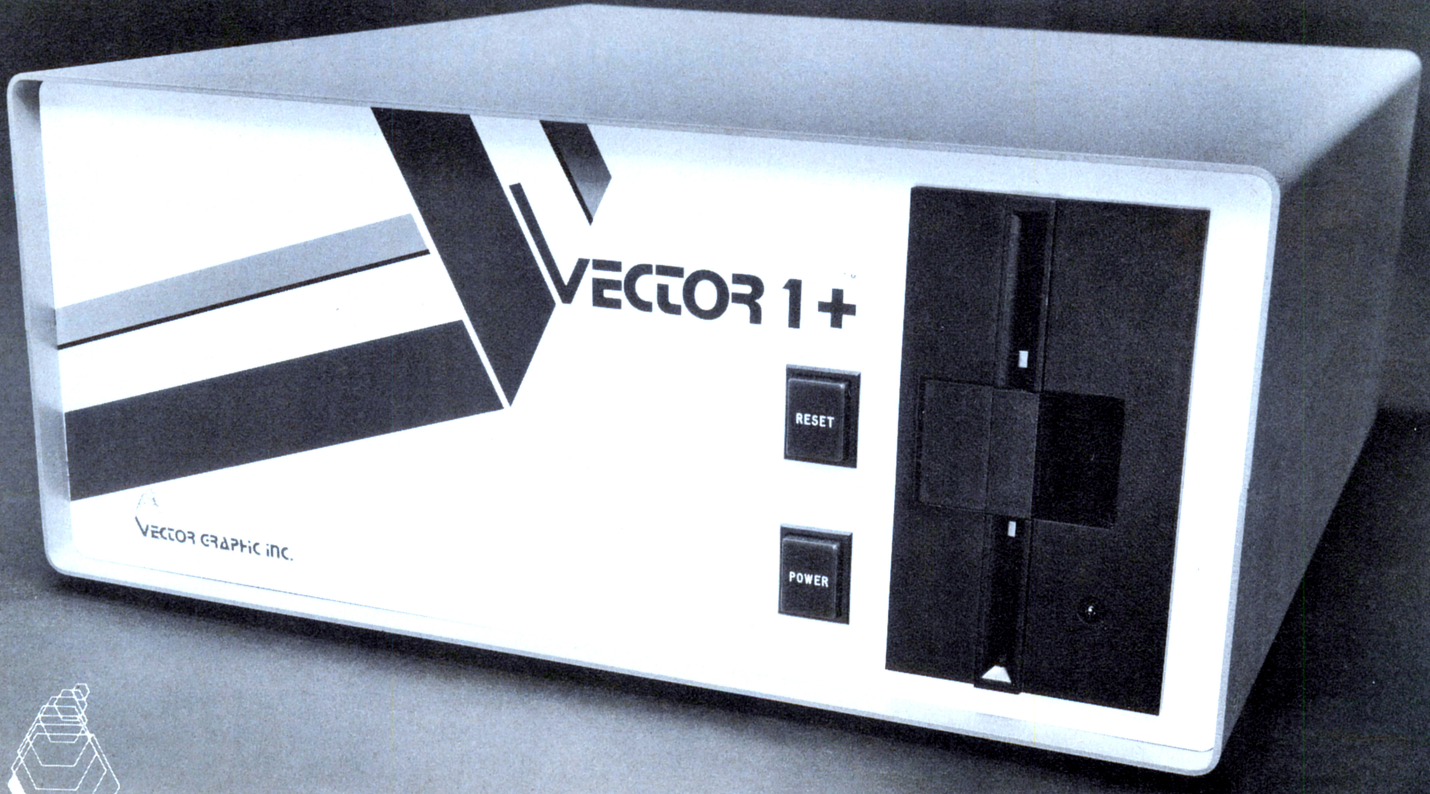

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Photo 1: The author's computer music system, which consists of an Altair 8800 computer with 32 K bytes of programmable and read only memory, and an ADM-III video terminal. Also pictured is a Mini-Moog electronic music synthesizer (top left) and a Farfisa VIP 400 electronic organ (bottom left).

SCORTOS:

Implementation of a Music Language

Hal Taylor
Interactive Music
Box 11
Arlington VA 22210

Perhaps nowhere can technology better serve the creative end of the music arts than through the computer. The computer has a natural affinity for the application to music since it is capable of carrying out processes which create and perform music. It can be programmed to learn any language the composer wishes to use to describe his musical ideas. It can manipulate the symbols of that language to produce transformations of the composer's original ideas. It can enlarge and improve the quality of the composer's creative output by allowing him to work in an interactive mode where he can hear his musical works performed within minutes of their conception.

The computer owes this affinity to its unerring accuracy and high bandwidth, qualities which its human inventors do not possess. The human mind is slow and noisy and requires years of exercise to achieve the coordination necessary to perform complex musical passages. Although the computer may never be able to match the expressive subtleties of a concert soloist, it is in some cases more suitable for the performance of music than a human being.

If a program can be devised to convert musical symbols to the sounds they represent, then the computer can be of value to the composer as a means of developing composition prototypes, that is, preliminary designs of musical works that he could hear performed before he copied the parts and gave them to the orchestra. An editing capability would also be available to him to alter the music until it produced the desired results. When the computer performed the work to his satisfaction, the original score and the instrumental parts could be published on a computer controlled plotter. With such a system the composer could avoid the drudgery of hand copying parts, and would be encouraged to experiment

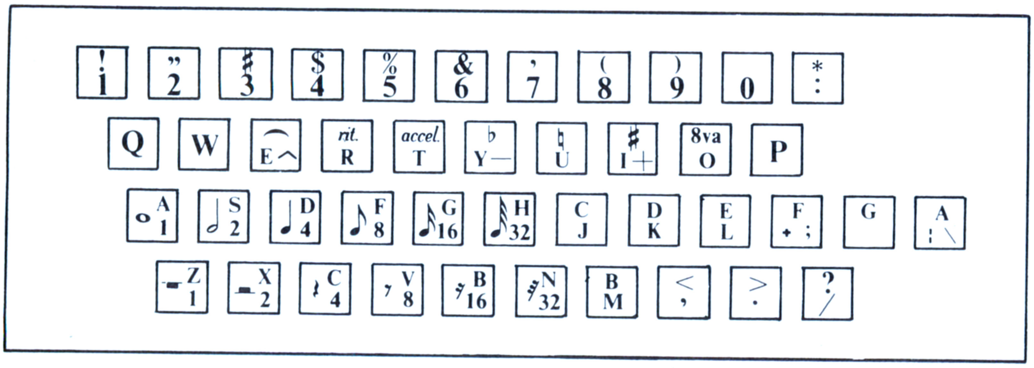

Figure 1: A standard alphanumeric keyboard modified for the SCORTOS language. SCORTOS is a language dedicated solely to the processing of musical information. The keyboard is a standard ASCII unit which has been relabeled with music symbols. The user enters a musical composition by striking the keys which correspond to the symbols in the music score of the composition (see also photo 2).

SCORE TO SOUND SYSTEM
MONITOR
"THE ENTERTAINER BY SCOTT JOPLIN"
ISi

Photo 2: The modified ADM-III video terminal. The keytops on the ASCII keyboard have been modified to enable the user to easily encode musical compositions. See figure 1.

with new forms that he might otherwise hesitate to give to an orchestra.

The computer can also be useful to the composer as an originator of musical ideas since it can simulate the process by which the human mind creates music. A music composition consists of a series of musical events chosen from a minimum of about 200 different possibilities (consider, just 12 tones and 18 types of notes). Only certain of these combinations are pleasing to the human ear. The composer's job is to discover those combinations which produce aesthetic results. The manner in which he or she does this is personal, intuitive, and cannot by itself form the basis for a workable algorithm. It is possible, however, to infer some of the underlying rules of music by analyzing it. Whether we are composing with our minds or with a computer, we follow a set of rules that determine which pitches will be chosen, in what order they will be arranged, and how long each will last in time.

The set of rules describes the style and structure of the music and can be represented in a computer by a statistical model. A process can be programmed into the computer that uses the model to decide which musical events are suitable for use in the composition. The process is one in which random choices are discarded according to a stochastic model. */According to Webster's, stochastic processes are processes based on the behavior of random variables. Random variables, in turn, are functions which are the result of statistical experiments in which each outcome has a fixed probability. For example, the number of spots showing if two dice are thrown is a random variable . . .* CM/ In order to produce a musical event, the program generates a random number which it associates with a variable such as pitch or time. The number is then subjected to the constraints of the model. The model is constructed by feeding specimens to an analysis program which are representative of the desired compositional style. The specimens are analyzed according to pitch, time and chord structure, and a probability matrix of n dimensions is generated, where n is the degree of order desired and represents the extent to which the analysis was carried out. As n increases, progressively more order is imposed upon the process, since more information is available to describe the

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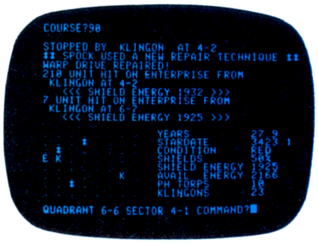

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Apple II™ is a completely self-contained computer system with BASIC in ROM, color graphics, ASCII keyboard, lightweight, efficient switching power supply and molded case. It is supplied with BASIC in ROM, up to 48K bytes of RAM, and with cassette tape, video and game I/O interfaces built-in. Also included are two game paddles and a demonstration cassette.

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  - Color graphics—40h x 48v, 15 colors
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  - Apple game I/O connector
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  - Speaker
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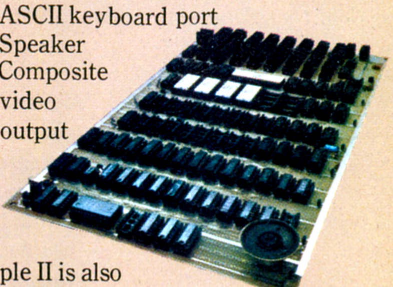

Apple II is also available in board-only form for the do-it-yourself hobbyist. Has all of the features of the Apple II system, but does not include case, keyboard, power supply or game paddles. $598.

PONG is a trademark of Atari Inc.

*Apple II plugs into any standard TV using an inexpensive modulator (not supplied).

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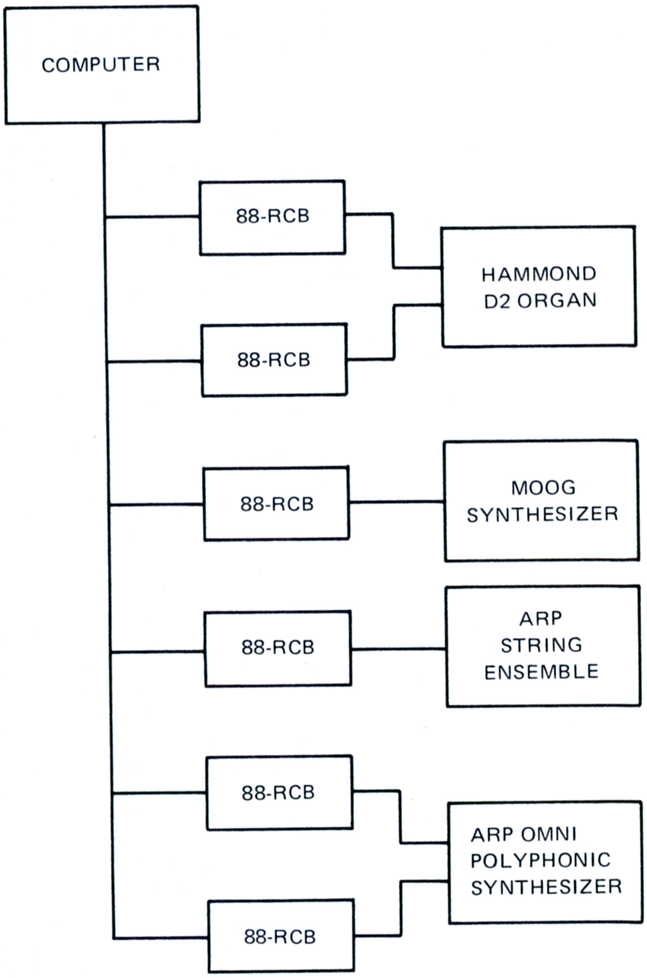

Figure 2: A medium scale SCORTOS configuration. The 88-RCB units are relay boards which can be driven by the computer to operate organs, synthesizers or other similar instruments. Each board consists of two 8 bit data registers which can be loaded from the central processing unit. Each of these bits in turn drives a transistor which energizes a relay. One 88-RCB board can control 16 keys, or 1 1/4 octaves of a musical keyboard. The system can address (and therefore control) up to 256 keys.

desired composition and less is left up to chance.

Zeroth order stochastic control is no control at all. Random choices are used to build the composition without testing them against the model producing unlistenable music in most cases. In *first* order control, the transitions between pitches and rhythms are governed by the probability distribution of those transitions as they occurred in all the analyzed samples. Music produced in this manner still sounds amorphous, but will have fewer pitches that sound alien.

It is not until we impose higher order control that a melody as we know it will take shape with its symmetrical phrases and regular intervals. In *second* order control, the selection of an event depends upon the event that preceded it; in *third* order control the previous two notes, and so on. For example, if the previous note chosen was a B-flat and the random number generator has just produced a C, the program refers to that location in the probability matrix which gives the probability of a C following a B-flat. If there is no probability of this happening, the C is rejected. If the probability is 1.00 then a C always follows a B-flat in this style of music, and the program will reject all random numbers that are not Cs.

Of course the source of the information within the model need not be music specimens, as in this example, but may originate from mathematical functions, poetry or any one of a hundred other sources. It is this capability which makes the computer so intriguing as a composer's tool.

The Score to Sound System

The Score to Sound System (SCORTOS) was developed to provide the composer with an inexpensive means of conducting computer implemented music research and composition prototype development. The system has the capability to perform conventional music scores by allowing music symbols to be entered through a terminal keyboard by an operator. Music of computer generated specifications can be performed through user program calls to a set of subroutines that interface the user program to the SCORTOS system software.

Music is produced by the computer driving relays that are wired in parallel to the keyboard switches of electronic music instruments – organs, synthesizers, etc. This allows a simple and inexpensive interface between the composer's studio instruments and the computer. The limitation of this approach is in its inability to provide the computer with access to the timbre controls of the synthesizer, an encumbrance which may be tolerable to experimenters primarily interested in the musical variables of tonality and syntax. Also, there is a rich assortment of preset timbres available in commercial keyboard instruments, among them, the Orchestron which generates actual orchestral and choral sounds from a prerecorded optical disk.

The system consists of an Altair 8800 computer with 32 K bytes of memory, an ADM-III video terminal, a mass storage device (either cassette or floppy disk), one or more International Data Systems 88-RCB relay control boards and any electronic keyboard instruments the user wishes to connect to the 88-RCBs.

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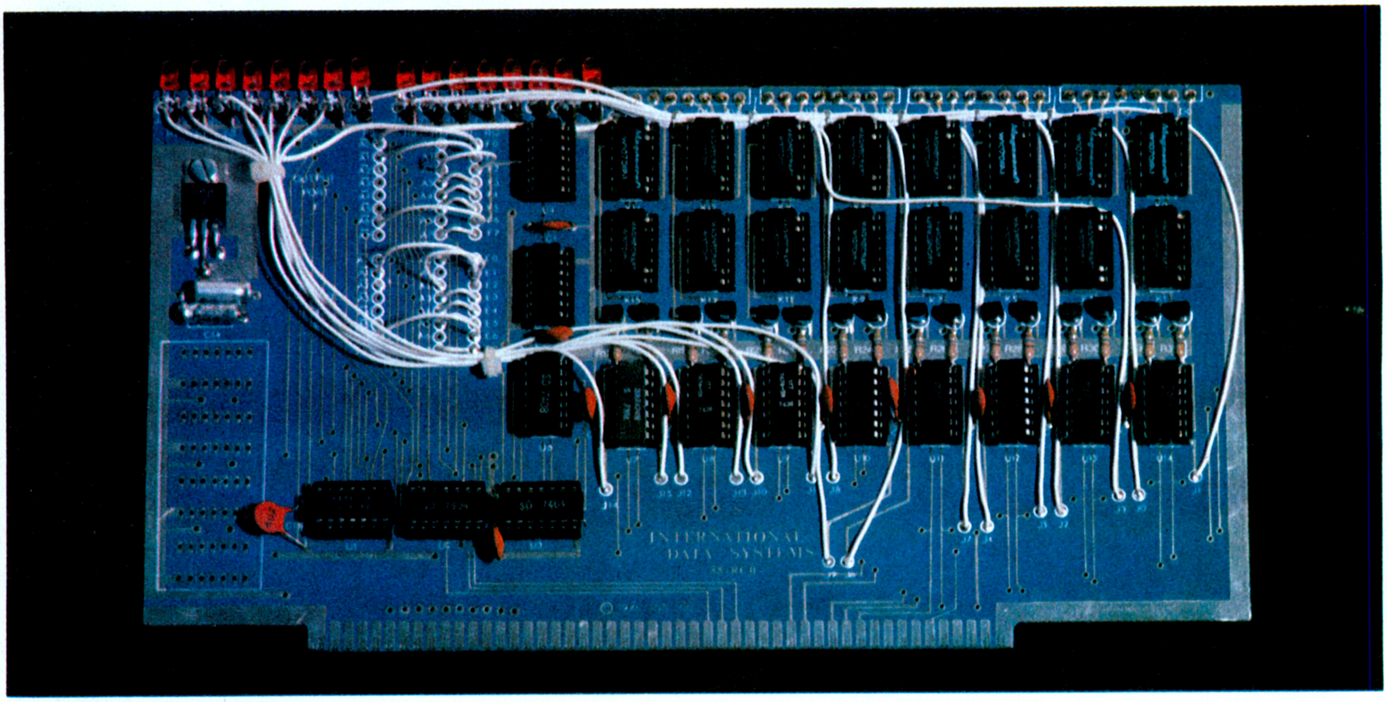

Photo 3: A close-up view of the component side of the 88-RCB 16 channel relay interface board which can drive a musical keyboard with signals from the computer.

board whose keytops have been relabeled with music symbols (see figure 1 and photo 2). The composer enters the composition into the computer by striking the key corresponding to each musical symbol as it appears in the score. This creates a music text file. The source text is passed to a language processor which maps each musical event represented in the source text into a physical IO address plus a timing value, and writes this to a binary output file. The result is a list of records each of which defines which key of which instrument will be turned on and for how long. The binary output of the language processor is read by a driver program which uses the IO addresses and timing values in each record to determine what data is to be loaded into the data registers of the 88-RCBs, and at what time it is to be loaded. The keyboard instrument responds by playing the piece just as if someone were playing on its keyboard. In fact, the system can be thought of as an organist with 16 very flexible fingers, because it is capable of performing 16 separate parts simultaneously.

Keyboard Instrument to Computer Interface

The 88-RCB is the interface between the computer and the electronic keyboard instruments. It was designed expressly for the SCORTOS system project, but is also useful for other low current switching applications. The board has two 8 bit data registers which are "write only" accessible to the central processing unit (CPU) through two output ports which are individually strappable to any address in the 8080 IO channel. The data register latches the contents of the CPU's A register when an OUT instruction has been executed to that register's output port address. The outputs of each bit of the data registers drive a transistor which in turn drives a board mounted DIP relay.

The complement outputs of the data register latches are used to drive light emitting diodes (LEDs) which can be mounted on the board or on a front panel to monitor the status of each relay. The relays are wired in parallel to the keyboard switches of the electronic music instruments which electrically isolate the peripherals from the computer and ensure plug-to-plug compatibility among most keyboard instruments. Each 88-RCB controls 16 keys, or 1 1/4 octaves of keyboard. To ensure an adequate tonal range, two 88-RCBs may be configured on any instrument (see figure 2).

The maximum number of keys the system can address is 256. In arriving at a figure of maximum connectivity, it was necessary to balance programming considerations against what was thought to be an adequate number of system-controllable sound producing peripherals. 256 keys are equal to about 20 octaves of keyboard (three full piano keyboards) which may be distributed among ten sound-producing peripherals, giving each instrument a 2 octave range. This maximum configuration seems adequate to provide for the largest studio application.

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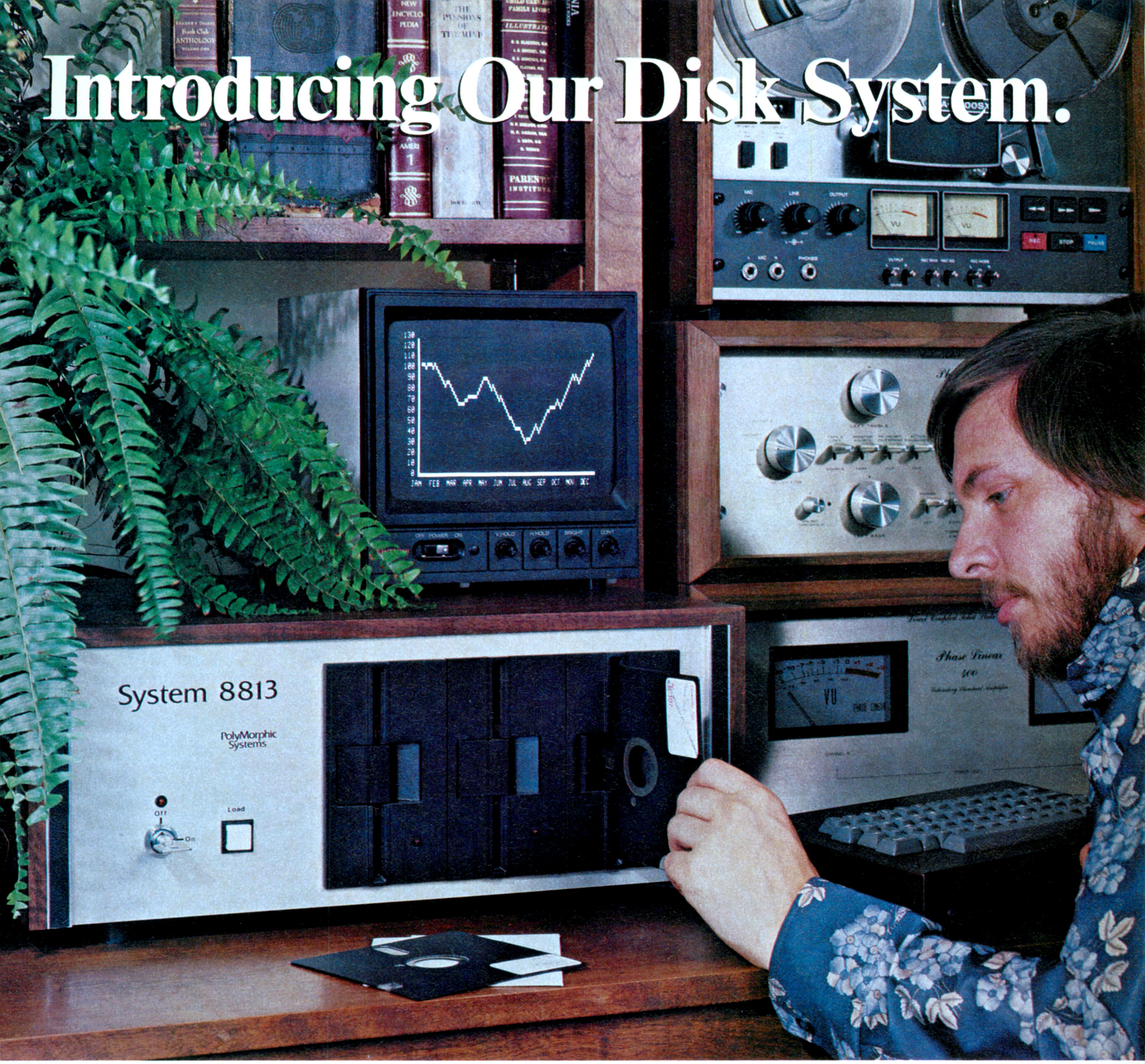

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Music Symbol	Description	SCORTOS Code	Music Symbol	Description	SCORTOS Code
𝅝	whole note	X1	𝄽	quarter rest	4
𝅗𝅥	half note	X2	𝄾	eighth rest	8
♩	quarter note	X4	𝄿	sixteenth rest	16
♪	eighth note	X8	𝅀	thirty-second rest	32
𝅘𝅥𝅯	sixteenth note	X16	𝄆	left hand repeat	[
𝅘𝅥𝅰	thirty-second note	X32	𝄇	right hand repeat	]
𝄻	whole rest	1	𝄀	bar	/
𝄼	half rest	2	𝅘𝅥𝅮𝅘𝅥𝅮𝅘𝅥𝅮 3	triplets	3(XnXnXn)

Music Symbol	Description	SCORTOS Code
C	Pitch representations	C
D		D
E		E
F		F
G		G
A		A
B		B
♯	sharp	+
♮	natural	N
♭	flat	—
♩‿♩	slur	Λ
.	dot	.

Table 1: The alphanumeric music coding convention used by the SCORTOS system. The X symbol preceding each numeric SCORTOS code symbol indicates that the numeric symbol must be preceded by a pitch representation before it can be recognized as a note. For example, C2 would be a half note with pitch C.

A simple method of representing keyboard address was chosen to minimize the execution time of the DRIVER program. One byte is used to represent the keyboard address (pitch), and one byte contains the length of time the event will last (rhythm). Since a music piece consists of so many events, the size of the data record is critical. It affects the total performance of the system by limiting the length of any performance to the number of event records that will fit in available memory. For this reason, it is not practical to increase the size of the event data record to accommodate a connectivity greater than 256.

The Alphanumeric Representation of Music

The conventional music score format is not the most perfect method for entering music into computers. The music symbols must be somehow transformed into a code the computer understands. In the conventional method, the operator enters data from a music score into an alphanumeric keyboard. This method has two disadvantages: it often requires multiple alphanumeric symbols to define one musical event (one character for pitch, one character for rhythm, one character for dynamics). The second disadvantage is that the choice of alphanumeric symbols must relate in some way to the quality of the musical symbols they represent, which in the past has meant that the symbols were scattered about the keyboard with no regard to their qualitative value. As a result, the data entry process was a hunt and peck procedure which may have been too discouraging for all but the most enthusiastic.

The human to computer interface should provide maximum ease in data entry and data editing. There are four ways to accomplish this:

- Choose a set of alphanumeric symbols to represent the set of musical symbols that will enable music passages to be

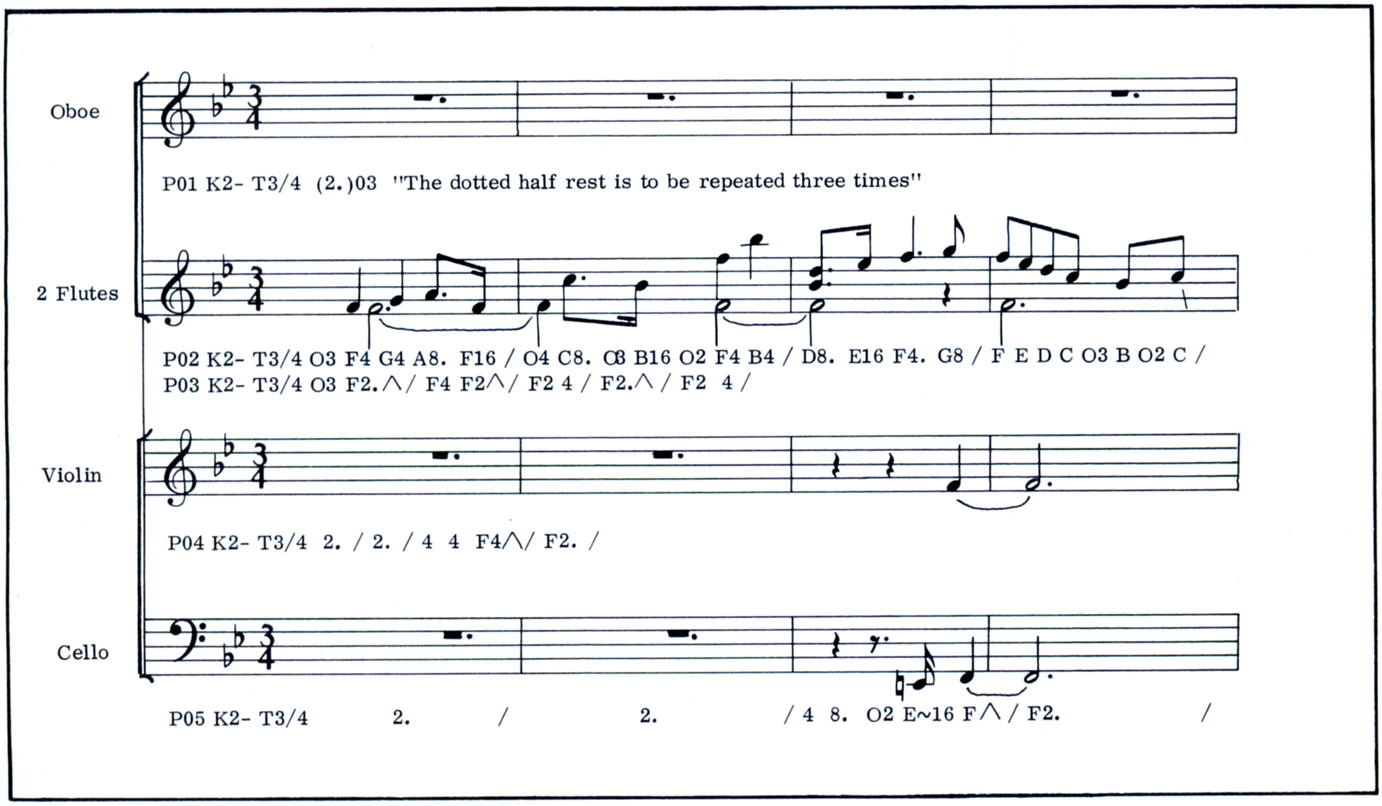
Oboe
P01 K2- T3/4 (2.)03 "The dotted half rest is to be repeated three times"
2 Flutes
P02 K2- T3/4 O3 F4 G4 A8. F16 / O4 C8. O3 B16 O2 F4 B4 / D8. E16 F4. G8 / F E D C O3 B O2 C /
P03 K2- T3/4 O3 F2.^/ F4 F2^/ F2 4 / F2.^ / F2 4 /
Violin
P04 K2- T3/4 2. / 2. / 4 4 F4^/ F2. /
Cello
P05 K2- T3/4 2. / 2. / 4 8. O2 E~16 F^ / F2. /

Figure 3: A fragment of an orchestral score annotated in SCORTOS code (see listing 1).

best recognized in alphanumeric form.

- Eliminate all redundancies in the music score.
- Position the alphanumeric symbols on the keyboard logically in the order of their musical value and group them by type.
- Generate bar markings and bar numbers automatically during data entry.

Table 1 shows the alphanumeric symbols used to represent conventional music notation in the Score to Sound System. Note that each alphanumeric symbol alludes to the quality of the music symbol it represents. A musical event can be defined by one or two symbols, depending upon whether the event is a rest or a note. A numeric symbol which is not preceded by a letter character is recognized as a rest. Notes always occur as a pair of symbols, that is, a letter character followed by a numeric symbol. Figure 3 illustrates a portion of an actual orchestral score along with its corresponding SCORTOS code.

Since the characters generated by the SCORTOS keyboard hardware do not correspond to those desired to represent the music symbols, the data entry software echoes back the desired character with the terminal in full duplex mode.

System Software

The SCORTOS System Software consists of a group of programs written in 8080 assembler language which carry out the four major functions of the system:

- entry and manipulation of the symbolic music text.
- conversion of the text to binary data.
- conversion of events initiated by user programs to binary data.
- conversion of the binary data to music.

The interaction of these programs with each other is shown in figure 4.

The monitor allows the user to control the system's major functions. It recognizes three command verbs with one or more arguments per verb. Each verb calls a system module, and its arguments specify the data file which is to be operated upon by that module. Table 3 is a list of command verbs recognized by the monitor.

The editor allows the user to enter music text through the terminal keyboard and provides a means by which it may be easily manipulated.

As text is entered through the keyboard, the editor's data entry processor keeps a running count of the bar number and auto-

Continued on page 206

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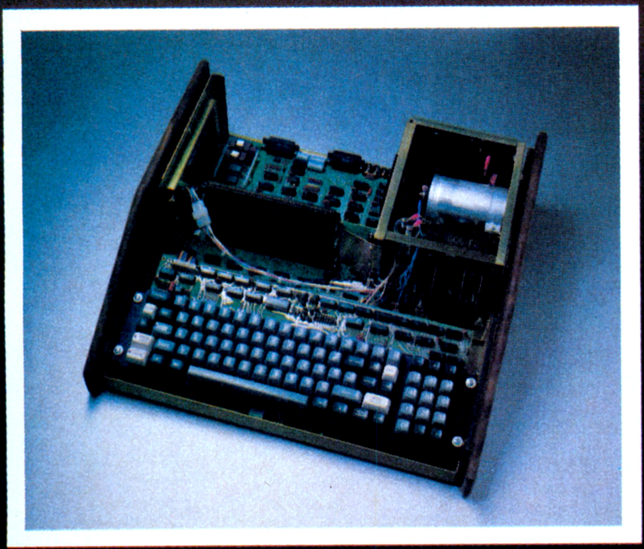

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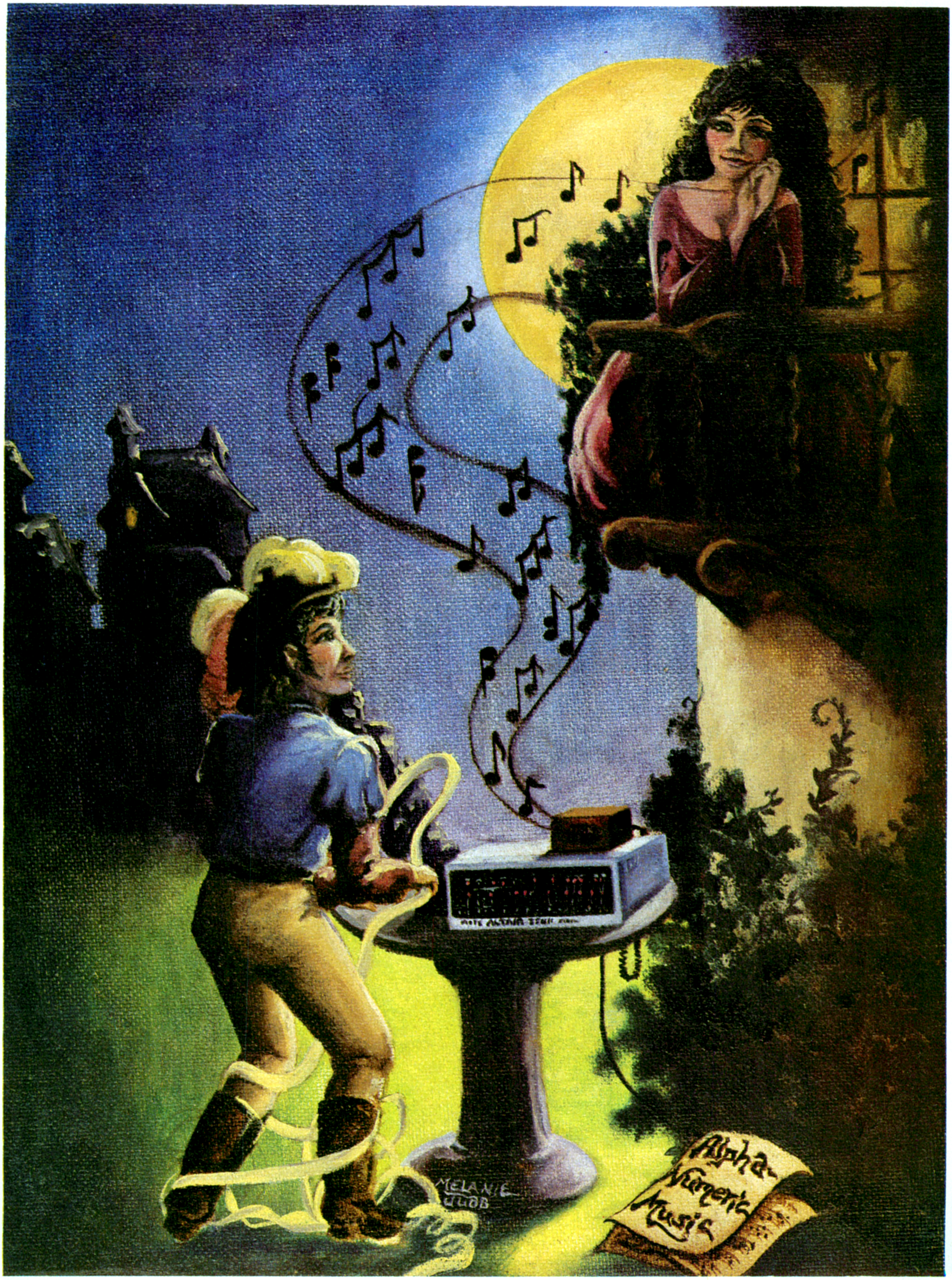
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Melanie Jubb's oil painting celebrates the idea of computers and music, emphasizing this issues's artistic themes. ■

A New Dress for KIM

(A Brief Case History)

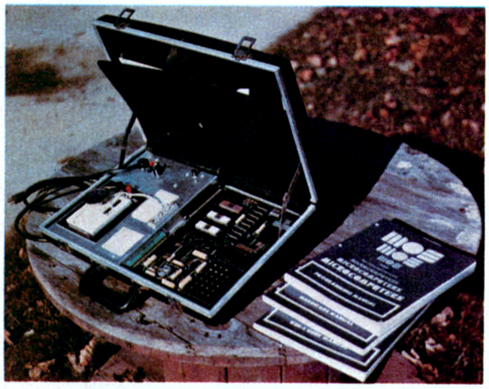


Photo 1: The author's new dress for KIM is shown in this shot taken with the briefcase opened. The unused area of the power supply cover is used to advantage as a place to mount prototyping boards for use in IO contexts with KIM.

R Travis Atkins
67 Greenend Av
Middletown RI 02840

At first I was reluctant to take KIM out in public because she was so small and homely compared to other systems her age. No one actually ever laughed at her in my presence, but I could sense the pity that they had for me. I wondered, would my KIM forever be overshadowed by those bristling brutish Altairs and IMSAIs at every social gathering? I knew KIM's strengths and her weaknesses, and I wondered if there was anything that I could do to help her find acceptance in the world. Then, one evening, while talking to a friend whose IMSAI was drawing considerable attention, as usual, it occurred to me that it wasn't his central processing unit's IQ that set it apart from my humble KIM. No, it was the way that it was dressed that did so much toward creating the image of great sophistication and power.

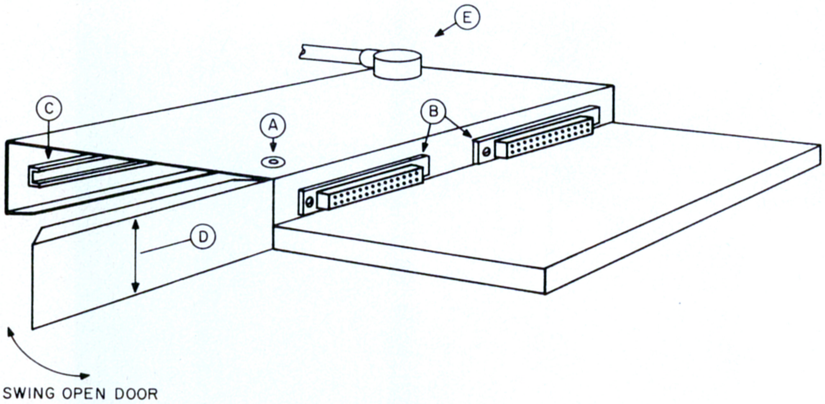


Figure 1: The assembly which was inserted into the briefcase has two sections at different levels as shown in this view. The section at the left covers a built-in power supply for the system. The lower section on the right faces two edge connectors (B) for the KIM-1 card. A single pop rivet hinge (A) allows a door to the power supply section to open. This allows the power supply card to slide out on the appropriate card guides (C). The power cord and other externals plug into the top of the chassis (E), which has enough area to accommodate prototyping cards as seen in photo 1. The height of the power supply section (D) is chosen based on the size of the briefcase.

I resolved that very evening to give my KIM the same advantages that her peers had; after all, who wants to be accused of neglecting loved ones? If she was to be ooo'd and aaah'd over, then she'd have to be dressed up before I took her out again. Although I must say honestly that I doubted that her 8.5 by 11 by 5/16ths dimensions would ever win her a spot on the centerfold of BYTE.

I suspect that there are many other KIM owners around who have also wondered how to dress up their bare-bones KIM board to take them out to club meetings and such, so here's the way that I did it. I hope it gives you some good ideas for your own KIM-1.

First of all, I had two major constraints to deal with: namely, my budget and my own skill, or rather lack of skill in the field of beautifully sculptured fiberglass and metal enclosures and the like. So I knew that I would have to settle for a simple and cheap approach to this thing. One thing that the KIM had going for it was its small size, because that meant that it could be placed inside a reasonably sized package. But, what was a reasonably sized package? And, where could I get one cheap?

A shoe box?. . .no, that's too big. Hey, how about that old briefcase in the back of my closet?. . .not a bad idea!

Much to my surprise and pleasure I discovered that those sneaky designers at MOS Technology must have been anticipating my train of thought, because when I opened that old briefcase and dropped the KIM in, it was a perfect fit! Great, now I knew what my enclosure was going to be, so the next question was how to support it inside the briefcase. Again, two constraints: first of all, protection for the printed circuit board itself, and secondly, reasonable looks.

The briefcase's exterior would provide some rough handling protection for the KIM, but it would also need some solid support from the bottom; therefore, since the bottom of my briefcase was not flat, I would have to construct a flat platform for the KIM. As for the basic appearance, I really wasn't too crazy about an open frame power supply, nor would that be an awfully safe setup. So, I decided that the power supply would have to be placed inside a special enclosure, away from stray fingers. The chassis design, shown in figure 1, was the result of considerable study.

Some of the more notable yet less obvious features of this design are:

- A swing open door to provide access to the power supply compartment (pop rivet hinge).
- The 44 pin edge connectors (one of which is provided with the KIM-1) penetrate the chassis wall to give solid support and to protect the loose wires.
- PC board edge guides to hold the power supply and other auxiliary components on a removable card.
- An overall height selected to suit the briefcase depth (mine filled the lower half).
- Placement of the power cord, switches, and other auxiliary parts on the top surface of the power supply compartment to facilitate easy removal of the entire assembly for bench work or to change to a new briefcase.
- A large surface to place connectors, etc.
- A Plexiglas cover sheet to further protect the KIM-1 board and filter the LED displays may also be added.
- Use of the upper half of the briefcase to carry documentation, etc.

The KIM-1 board is recessed in this design, but it is not hard to get to the keyboard for programming it, although this was one thing that I thought might give me trouble at first. Being recessed does give the KIM an added amount of protection, and I have found that the recess over the board is a great place to carry my KIM-1 owner's manual. That spares me from having to explain what in the world I have in my briefcase every time I open it in public.

The auxiliary area on top of the power supply compartment is the place where you can customize your chassis to suit your own particular needs. On my chassis I put a surplus 50 pin connector which is wired to most of the pins of the A connector, and selected pins of the E connector of my KIM board. I use this to patch into a small prototype board which I also placed on that surface, and I must say this has proven to be a most useful setup. Of course, you will probably want to provide jacks for your audio cassette unit, and maybe one for a Teletype if you're fortunate enough to have access to one.

At any rate, my little KIM is no longer the club wallflower, and as I look into her future I see a handsome genuine calfskin briefcase waiting.■

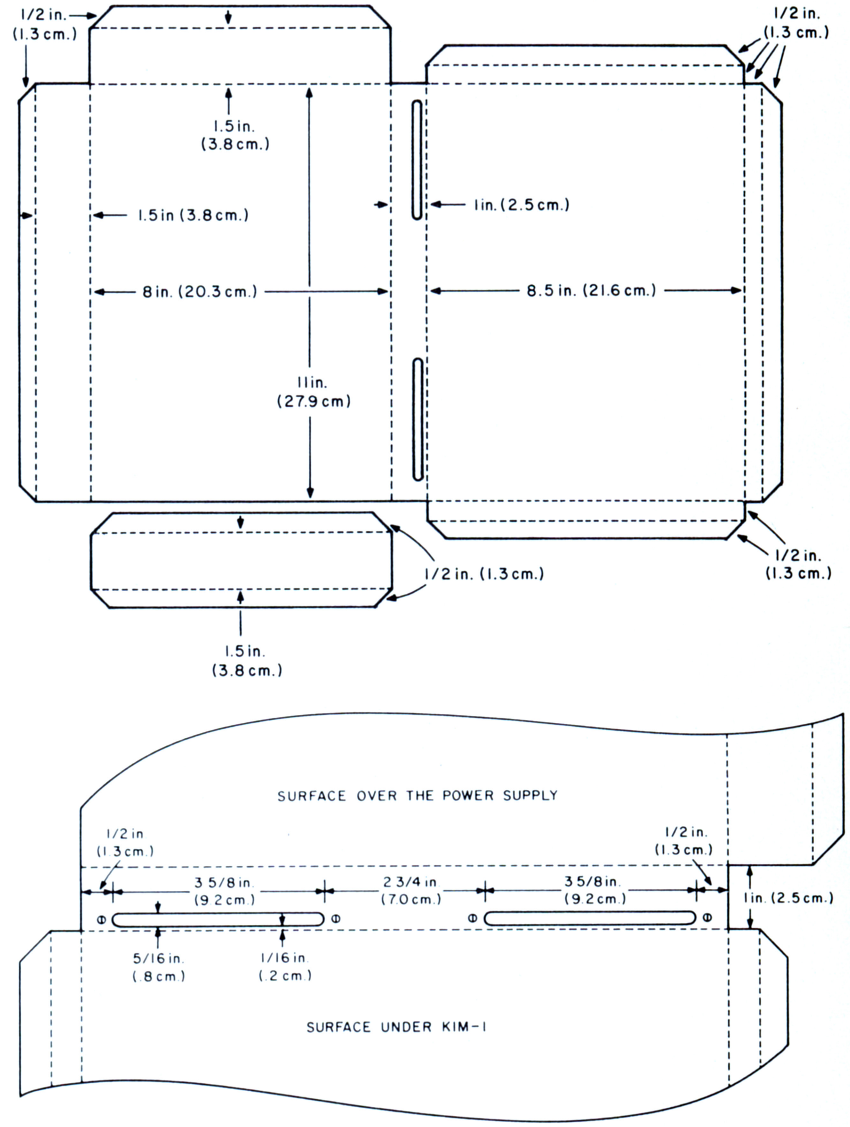
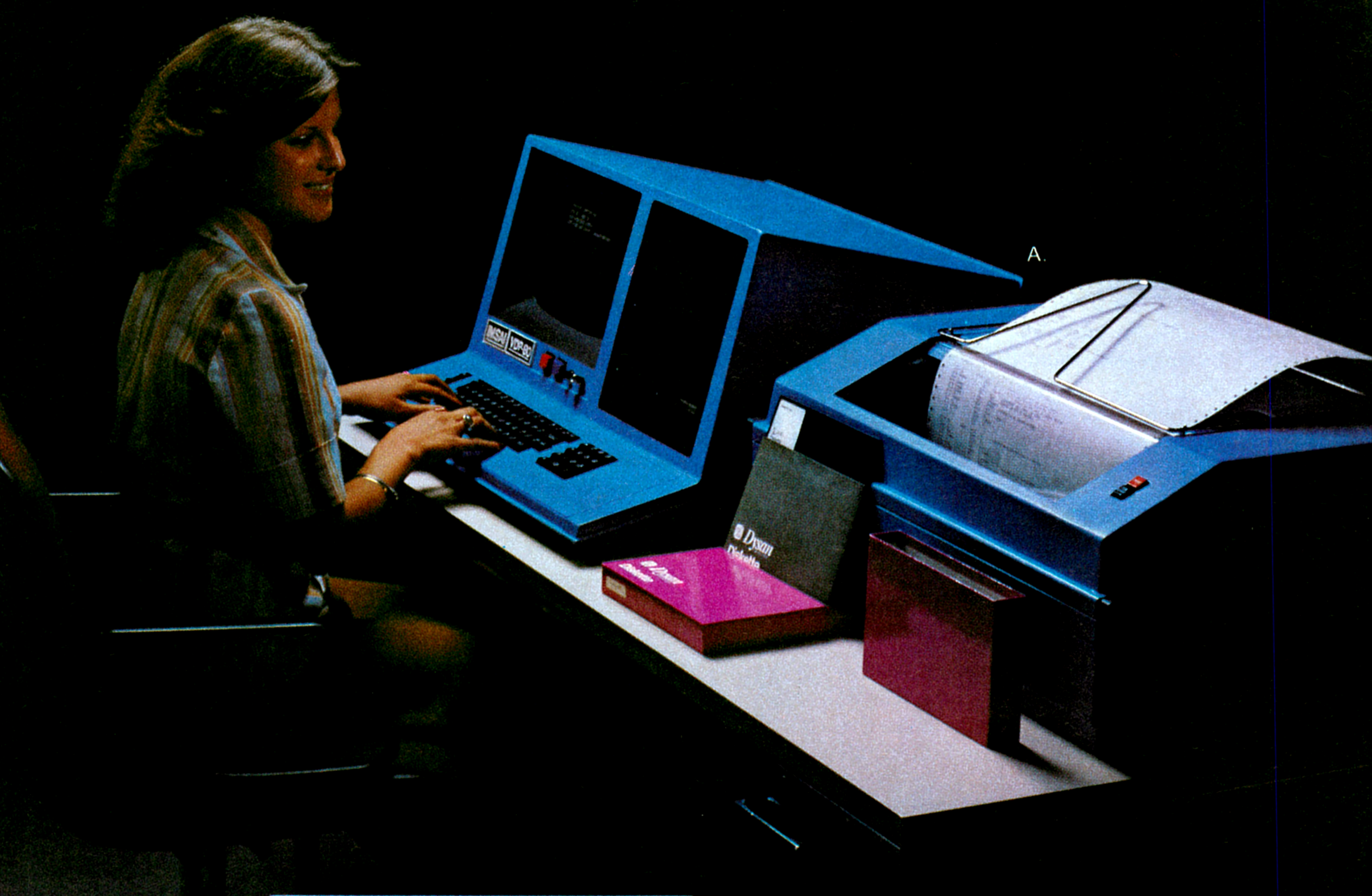


Figure 2: The mechanical design of the chassis box is shown in this illustration. The depths of the two sections are dimensioned to fit the author's briefcase. This can be fabricated out of a piece of aluminum stock 1/6 of an inch thick and measuring 20.5 by 15.5 inches (or, in integral metric dimensions, 2 mm thick measuring 52 by 39 cm). The drawings show dimensions for the actual KIM-1 connector holes with metric dimensions in parentheses. The housing was cut, milled (the pin edge connector holes) and constructed at a local machine shop for under $15.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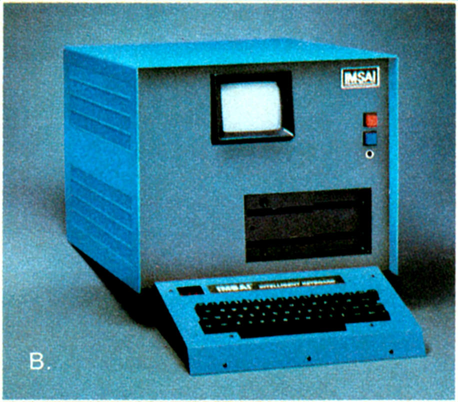
VDP-80
Dysan
Diskette

A.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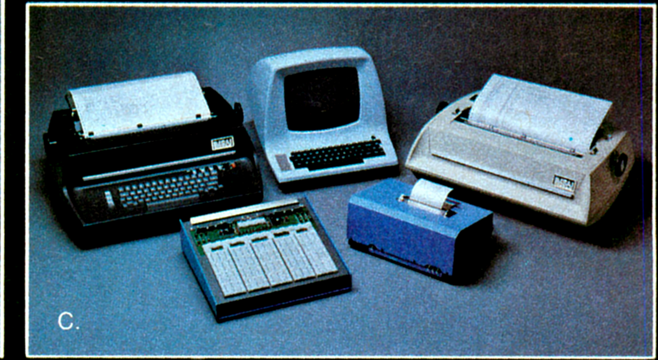

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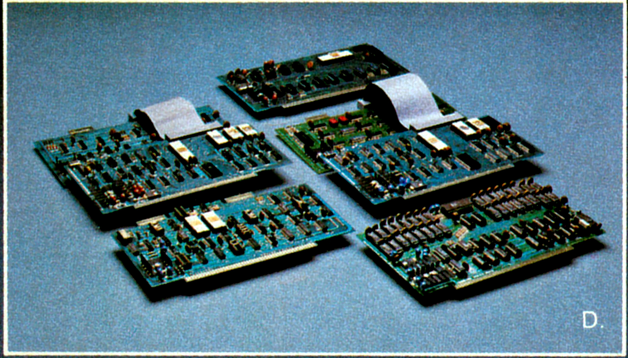

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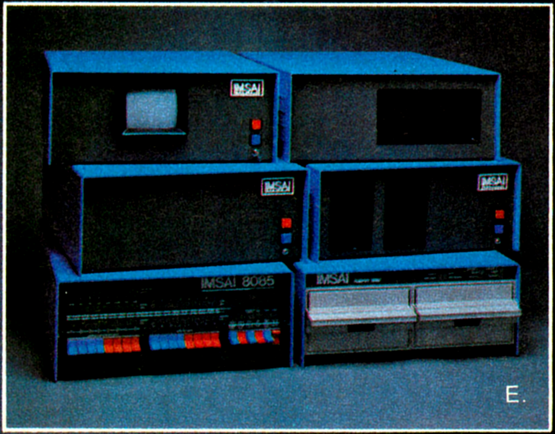
IMSAI
IMSAI 8085
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E.

A. VDP-80 Computer with 300 lpm printer.

B. PCS-80 with CRT, dual floppy disk & Intelligent Keyboard options.

C. Peripherals—(clockwise from left) 45 cps daisy-wheel printer/terminal, 24x80 CRT terminal, 45 cps daisy-wheel printer, Intelligent Breadboard, 44 col. alphanumeric line printer.

D. Processor, Memory & Interface boards—shown MPU-A, 65K RAM, and floppy disk, line printer and serial I/O's.

E. PCS-80 System—sample component configurations.

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- DMA—For floppies & line printers.

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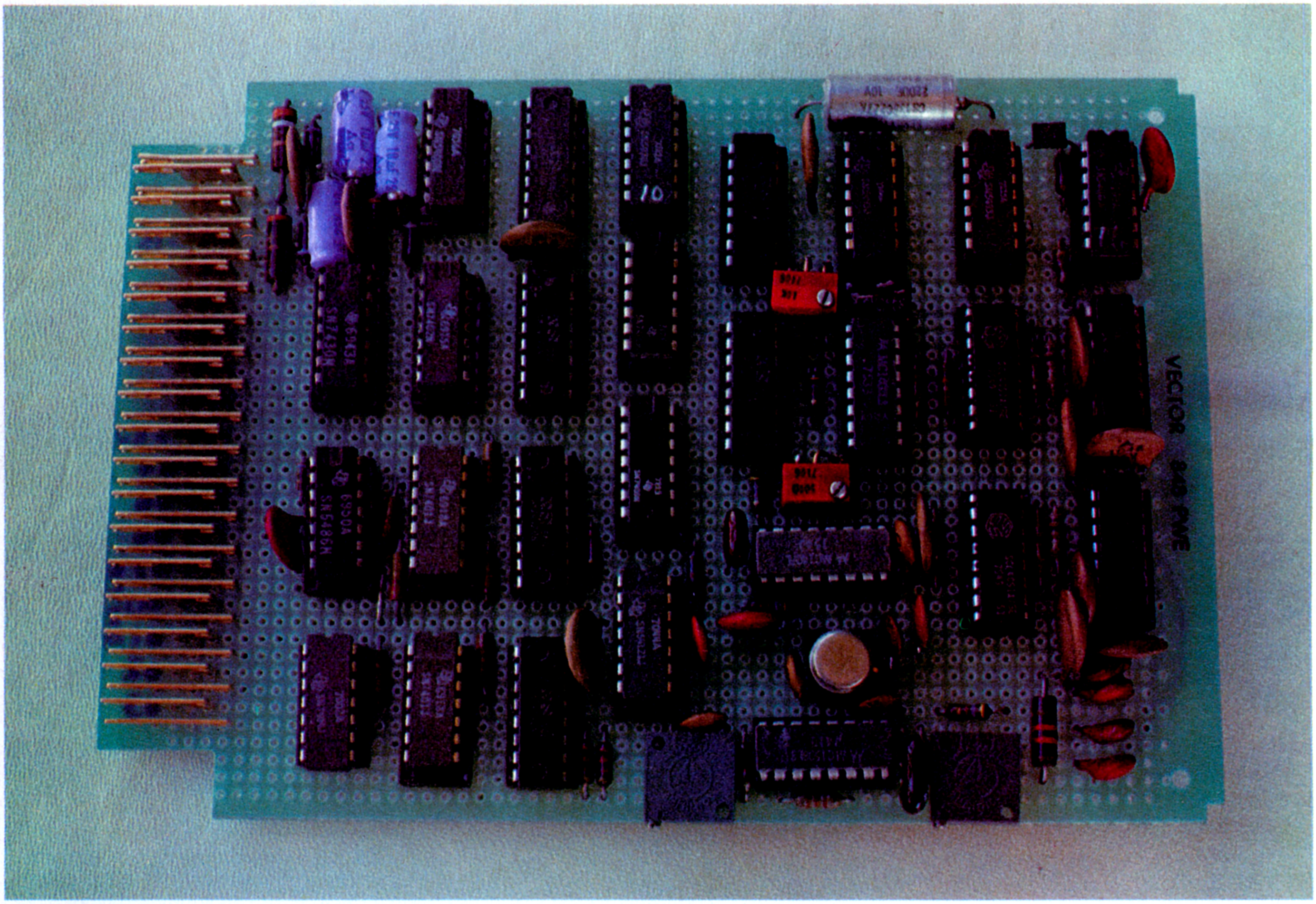

Photo 1: The author's prototype for the 4 channel self-refreshing digital to analog converter shown in figure 9. Also contained on the board is a prototype 4 channel analog to digital converter circuit.

Control the World!

Steve Ciarcia
POB 582
Glastonbury CT 06033

(Or at Least a Few Analog Points)

"Ka-chunk! OK, get the reading quick! Ka-chunk! Pop! Pop! Bang!! The darn thing crapped out again! We'll never get one of these detectors to pass a life test."

The burly mechanic puffed his fat cigar and with a disgusted sigh continued, "The dime store engineers who design these kludges should be the ones who have to test them! That's if you could ever get them out of that puzzle factory upstairs!"

That was my cue. I was indeed an engineer descended from the puzzle factory and my mission was to discover why we were having so much trouble life test qualifying one of the pressure detectors we intended for future manufacture. Hearing the preceding commentary as I approached the testing lab, I decided that an authoritative professional type would not be very popular at the moment, so I went into my innocent nonmanagerial mode and entered the lab.

This lab was not unlike any other small production qualification and testing lab. It had the usual machinery and instrumentation and many artifacts of former test programs lying about. The most prominent

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artifact was the leader of the instrumentation group, Ned. Ned's large frame amply filled the white lab coat though it was barely discernable in the dense cloud of cigar smoke. The combined scent of hydraulic oil, burned resistors, and cigar smoke convinced me that today was not going to be my day.

"Hi, Ned. What's the problem with the new detector?", I asked.

"It's about time one of you guys came down and asked. This has got to be the most fragile pressure detector I have ever tested. So far, we have wiped out four engineering prototypes and haven't gotten to 20,000 pressure cycles, let alone the 50,000 life test," he bellowed.

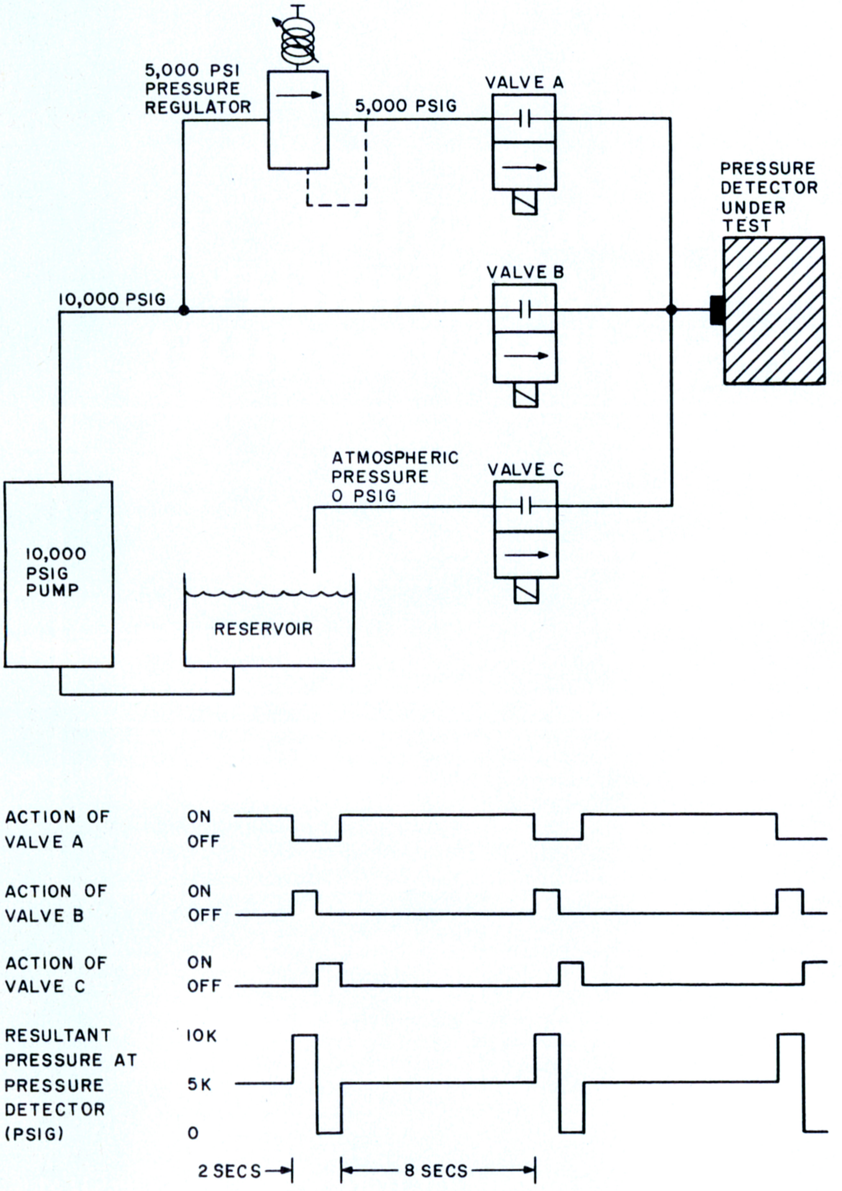

Figure 1: Configuration of a conventional impulse pressure calibration test setup. Note that the pressure detector under test receives what amounts to a square wave input. This type of violent pressure change can shorten the life of the detector and give a false indication of its long term life expectancy. PSIG, or "gauge pressure," is explained in the text.

My eyes rolled slightly as he mentioned the failed units. These pressure detectors were not in the least bit fragile; they were ruggedized units with a prospective sale price of $4700 each. The four engineering prototypes were handmade and far more costly. Before it became too apparent that I was coming to a slow burn, I asked the obvious question. "Ned, are you following the engineering test specification?"

"You guys are really something! I've been in this business for 30 years. I was testing . . ."

"OK, OK, Ned! Just tell me what your test procedure is. Pretend I'm a novice and tell me by the numbers." I was sure that he felt that was the way he had to work with any engineer, so I humored him and just listened.

"All right. The pressure detector is rated at 7500 PSIG and we are life testing it," he said with a cigar chomping smile. "The pressure is cycled between 0 pounds per square inch gauge (PSIG) and 10,000 PSIG every ten seconds and remains at 5,000 PSIG between cycles. *[PSIG, or gauge pressure, is a differential pressure measurement using the ambient pressure as a reference. Usually, standard sea level pressure (14.7 pounds per square inch) is used as the reference . . .*CM*]* At the conclusion of each cycle, the detector reading is compared to an out-of-tolerance spec. Oven temp and other control parameters are constantly monitored. Every 10,000 cycles, a calibration run is taken and compared to the accuracy specification quoted. We just haven't been able to get one of the bloody things to hang together long enough to finish the test. The pressure diaphragm keeps breaking."

So far, what he was relaying was exactly the procedure I had outlined. Nothing sounded wrong, so the next obvious question was a description of the test apparatus.

"I decided to automate the testing procedure," he gleamed like a kid describing a new toy. "I made a sequencing circuit with relays to cycle the pressure automatically. All the operator does is record the data and run the calibrations. Here, let me draw you a diagram."

It was unbelievable! True, Ned was following the spec, but what a way to do it! Pressure transducers are expected to withstand a certain amount of overpressuring, which was the reason for the test. But overpressure in combination with a 10,000 PSIG

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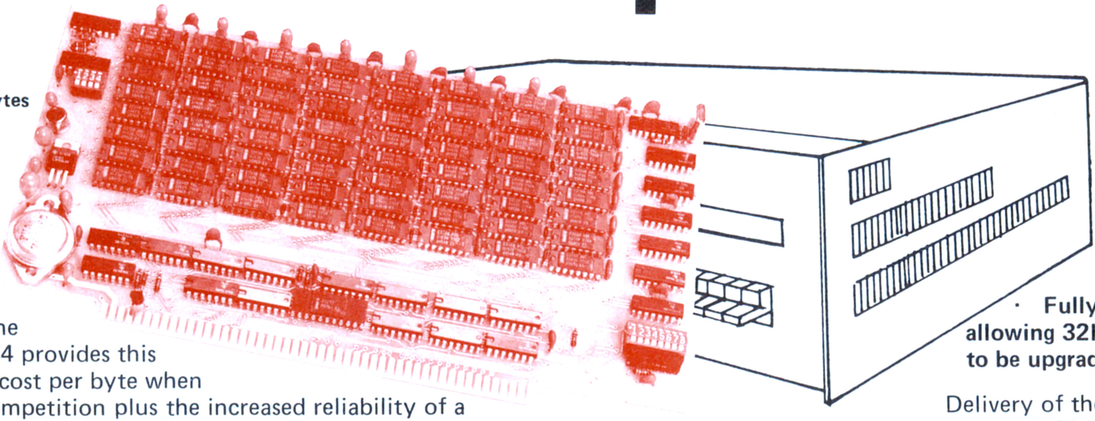

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impulse was like a jackhammer. The engineering group upstairs would be amazed that the test made it though 20,000 cycles. I wiped my brow, leaned against the concrete wall and asked with a pathetic whimper, "I suppose the failed detectors make good boat anchors."

"What?", he asked, not having heard what I had said.

"Ned, while I think your intention is fine, your method may be a little too rough on the unit. Why don't we change the square wave pressure being applied to the detector to a sinusoidal waveform." This was the method I had assumed he was going to use initially.

"I can't have a guy sitting there cranking a pressure controller knob ten hours a day. It's going to take two weeks to run this test as it is. That's why I automated it!" He seemed to get mad as I challenged his inventiveness.

"You don't have to compromise anything. Get a DC proportional control valve from the stock room and modulate the pressure sinusoidially. In fact, you can use the minicomputer which you ordinarily use for mathematical calculations over there in the corner to drive it directly, collect the data, and run the calibration automatically."

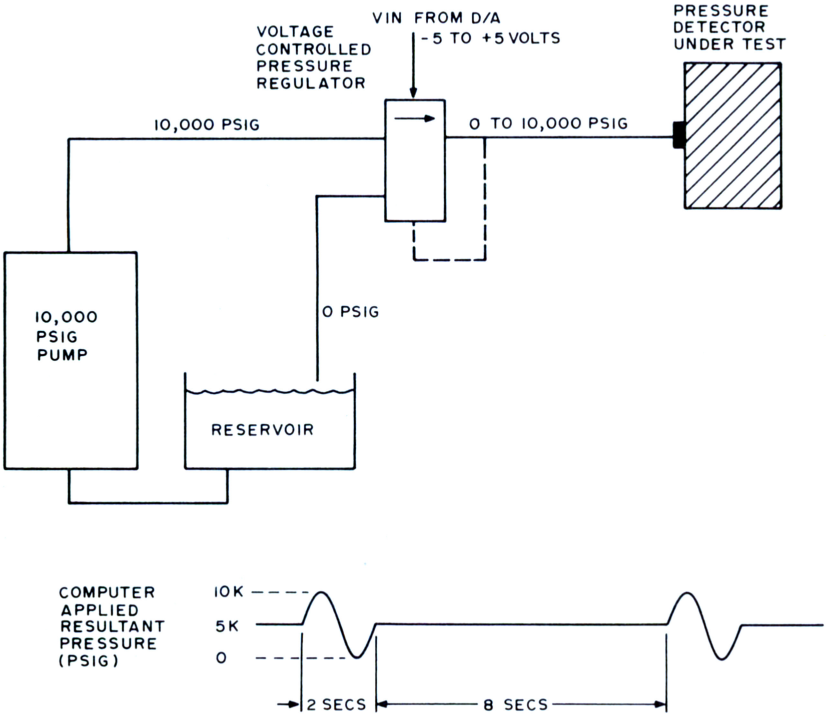
VOLTAGE CONTROLLED PRESSURE REGULATOR
VIN FROM D/A
-5 TO +5 VOLTS
PRESSURE DETECTOR UNDER TEST
10,000 PSIG
0 TO 10,000 PSIG
0 PSIG
10,000 PSIG PUMP
RESERVOIR
COMPUTER APPLIED RESULTANT PRESSURE (PSIG)
10K
5K
0
2 SECS
8 SECS

Figure 2: The same pressure detector as in figure 1 being tested here with a computer controlled system which applies the test pressure sinusoidally. This approach gives a much better indication of the unit's true life expectancy, and incidentally shows one practical application of digital to analog conversion.

"You guys upstairs must be suffering from thin air. I know about computers; ones and zeros and all that stuff. We're talking about a DC voltage controlled valve. That isn't consistent with computer binary voltage levels. You would have exactly the same on and off situation as my relay controller," he stated.

It was going to be an uphill fight, but I knew I was going to have to introduce Ned to the world of analog to digital and digital to analog conversion. I first mapped out the life test circuit and diagrammed the waveforms.

Ned was no neophyte. He felt that he knew a lot about computers and in fact was quite familiar with the uses of BASIC and FORTRAN on the lab minicomputer. But Ned had never considered that this number crunching machine has the same logical abilities to control analog devices if properly interfaced.

General Considerations

While this may have been a lengthy introduction to computer analog interfacing, it often takes a real life situation to make one realize the added potential of the computer when it is combined with analog capabilities.

Since natural parameters such as displacement, temperature, volume and magnetic field strength are analog, and most practical methods of data acquisition, manipulation and visual presentation are digital, conversion between analog and digital qualities is a fundamental operation in computing and control systems. The basic building blocks are the digital to analog converter (DAC), and the analog to digital converter (ADC).

Because these converters are essentially interface devices, the basic conversion circuitry must be adapted to properly mate the application to the computer. Such variables include the possible necessity for buffers, registers, clock circuitry and reference voltages, all of which are external supports for the actual conversion device. The exact design requirements can be lengthy and are handled separately by necessity. Digital to analog conversion is the first topic to be discussed.

Digital to Analog Conversion

The digital to analog converter can be thought of as a digitally controlled programmable potentiometer which produces an analog output. This output value (V_O) is the product of a digital signal (D) and an

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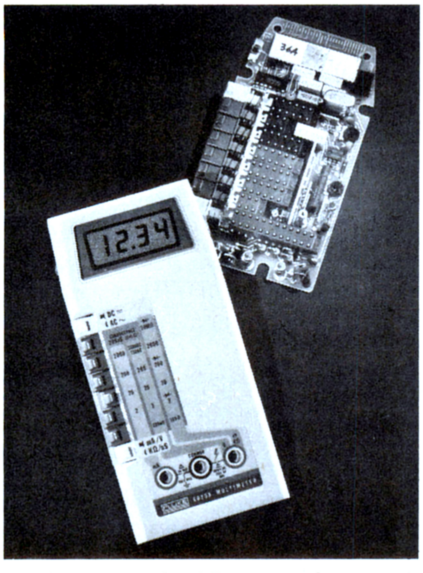

Why not analog? Because the 8020A has 0.25% dc accuracy, and that's *ten times better* than most analog meters.

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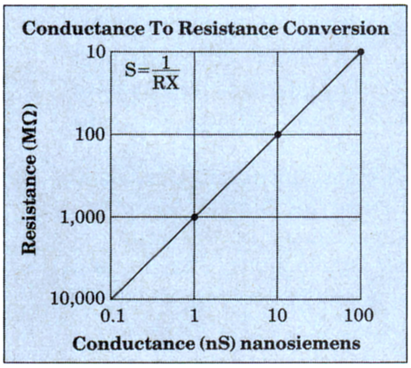
Nanosiemens?



Beginner or pro, you'll find the meter you now have can't measure nanosiemens. So what? With the 8020A *conductance* function, you can measure the equivalent of 10,000 megohms in nanosiemens. Like capacitor, circuit board and insulation leakage. And, you can check transistor gain with a simple, homemade adapter. Only with the 8020A, a 13-oz. heavyweight that goes where you go, with confidence.

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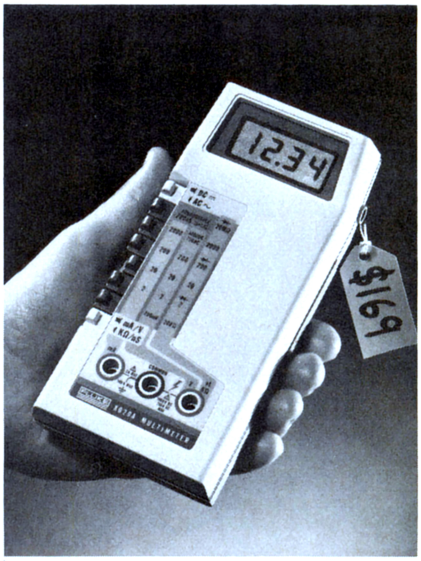

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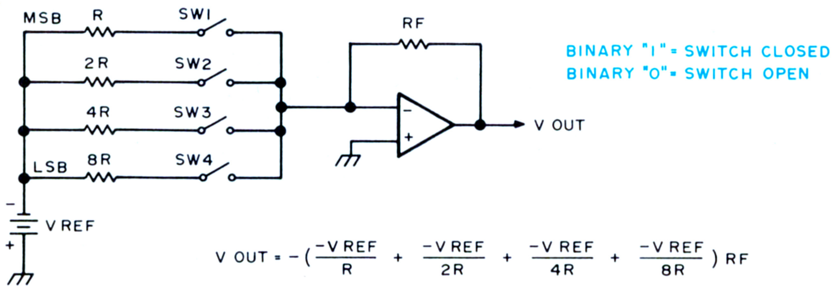

$$V\,OUT = -\left(\frac{-V\,REF}{R} + \frac{-V\,REF}{2R} + \frac{-V\,REF}{4R} + \frac{-V\,REF}{8R}\right) RF$$

Figure 3: A 4 bit weighted resistor digital to analog converter. A 4 bit word is used to control four single-pole single-throw switches. Each of these switches is in series with a resistor. The resistor values are related as powers of 2, as shown. The other sides of the switches are connected together at the summing point of an operational amplifier. Currents with magnitudes inversely proportional to the resistors are generated when the switches are closed. They are summed by the op amp and converted to a corresponding voltage.

analog reference (V_{ref}) and is related by the following equation:

$$V_o = (D)\ (V_{ref})$$

To a large extent, no digital to analog or analog to digital converter can be of much practical use to anyone without specifying the type of code utilized to represent digital magnitude.

Converters work with either unipolar or bipolar digital codes. Unipolar includes straight binary and binary coded decimal (BCD). Even floating point converters have been used on occasion: witness the auto ranging digital voltmeter. Offset binary, one's and two's complement and Gray code are usually reserved for bipolar operation. Since the obvious sphere of this article is home computer applications, straight and offset binary will be the only digital methods addressed.

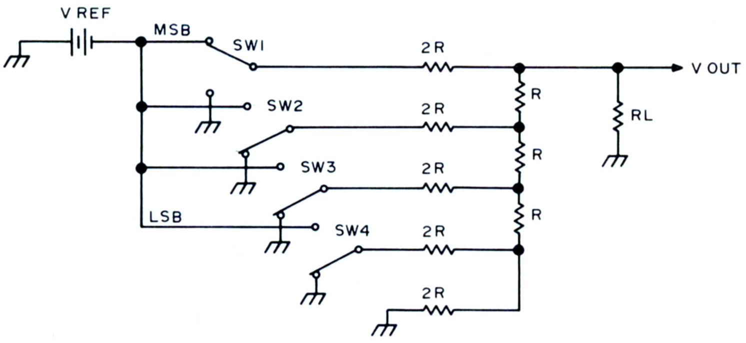

Figure 4: A 4 bit "R – 2R" ladder network digital to analog converter. This type of digital to analog converter makes use of a resistor ladder network constructed with resistors of values R and 2R. The topology of this network is such that current flowing into any branch of a 3 branch node will divide itself equally through the two remaining branches. Because of this, the current will divide itself in half as it passes through each node on its way to the end of the ladder. The four switches are again related as powers of 2. The position of each switch with respect to its distance from the end of the ladder determines its binary significance.

It is important to remember that the binary quantity presented by the computer is a representation of a fractional value to be multiplied by a reference voltage. In binary fractions, the most significant bit has a value of 1/2 or 2^{-1}, the next most significant bit is 1/4 or 2^{-2}, and the least significant bit is $1/2^N$ or 2^{-N}. It can be seen that adding up all the bits approaches a value of 1. (The more bits, the closer the value is to 1). The discrepancy between the binary value approaching 1 and the actual value 1 is the quantization error of the digital system. I'll discuss this later.

Offset binary is nothing more than straight binary except that the binary number zero is set to represent the maximum negative analog quantity. In the easiest terms, the most significant bit is a zero for negative analog values, and a one for positive analog values.

The conversion of digital values to proportional analog values is done by either of two basic conversion techniques: the weighted resistor digital to analog converter and the R–2R digital to analog converter. The weighted resistor digital to analog converter is by far the simplest and most straightforward. This parallel decoder requires only one resistor per bit. In the weighted resistor digital to analog converter, switches are driven directly from the signals that represent the digital number D. Currents with magnitudes of 1/2, 1/4, 1/8, . . .$1/2^N$ are generated by connecting resistors with magnitudes of R, 2R, 4R, . . .2^NR between a reference voltage, $-V_{ref}$, and the summing point of an operational amplifier by means of a set of switches. The various currents are summed and converted to a voltage by the operational amplifier (see figure 3).

While this may appear to be a simple answer to an otherwise complex problem, this method has some potentially hazardous ramifications. The accuracy of this converter is a function of the combined accuracies of the resistors, switches (since all switches have some resistance) and the op amp. In conversion systems of greater than ten bits resolution, the magnitudes of the resistors become exceptionally large and the resultant current flow is reduced to such a low value as to be lost in circuit noise.

A reasonable alternative to the weighted resistor digital to analog converter is the R–2R converter. This is often referred to as a resistor ladder digital to analog converter. The R–2R digital to analog converter is the most widely used type of digital to analog

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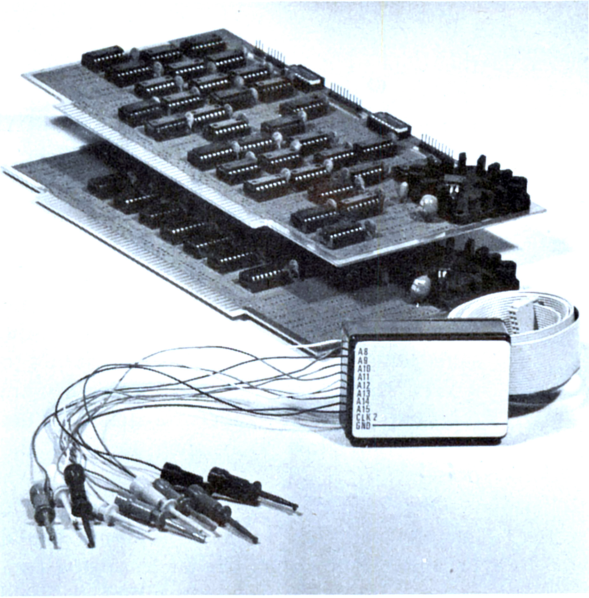

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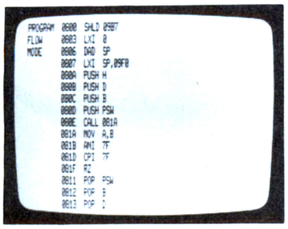

```
PROGRAM  0000  SHLD 09B7
FLOW     0003  LXI  0
MODE     0006  DAD  SP
         0007  LXI  SP,09F0
         000A  PUSH H
         000B  PUSH D
         000C  PUSH B
         000D  PUSH PSW
         000E  CALL 001A
         001A  MOV  A,B
         001B  ANI  7F
         001D  CPI  7F
         001F  RZ
         0011  POP  PSW
         0012  POP  B
         0013  POP  D
```

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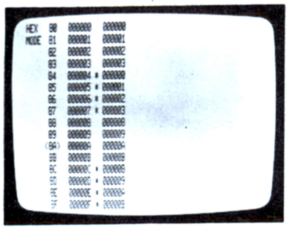
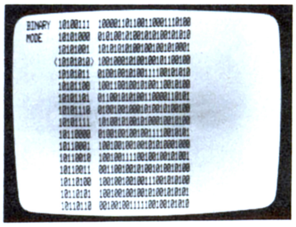


```
HEX   00  000000   000000
MODE  01  000001   000001
      02  000002   000002
      03  000003   000003
      04  000004 * 000000
      05  000005 * 000001
      06  000006 * 000002
      07  000007 * 000003
      08  000008   000008
      09  000009   000009
     (0A) 00000A   00000A
      0B  00000B   00000B
      0C  00000C * 000008
      0D  00000D * 000009
      0E  00000E * 00000A
      0F  00000F * 00000B
```

Displays in Hex



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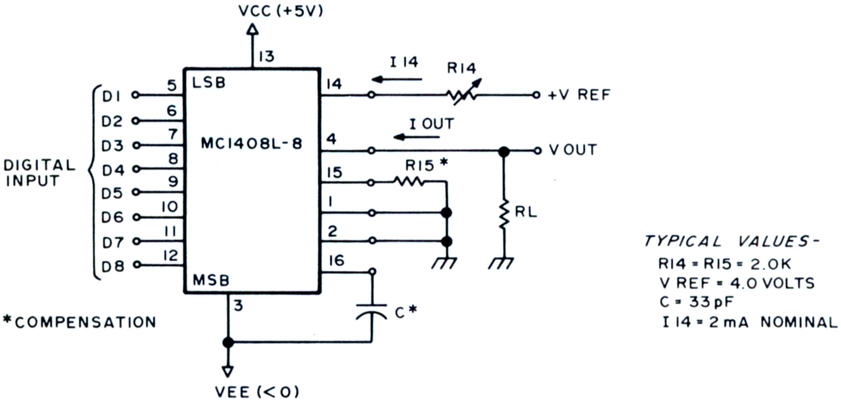
Number ____________________
Signature ____________________



$$I\ OUT = A\left[D1/2 + D2/4 + D3/8 + D4/16 + D5/32 + D6/64 + D7/128 + D8/256\right]$$

WHERE $A \simeq V\ REF/R14$
AND $DN = 1$ FOR HIGH LOGIC LEVEL
$DN = 0$ FOR LOW LOGIC LEVEL

Figure 5: A typical current output monolithic multiplying digital to analog converter. This Motorola integrated circuit contains an R – 2R network like the one in figure 4 plus additional current switching logic. The relative accuracy of this 8 bit unit is ±1 least significant bit, or 0.19% of full scale.

converter, even though it uses more components. This circuit is illustrated in figure 4 and also contains a reference voltage, a set of binary switches and an op amp, but the basis of this converter is a ladder network constructed with two resistor values, R and 2R.

One resistor (2R) is in series with the bit switch, while the other (R) is in the summing line, so that the combination forms what electrical engineers call a "pi" network. This suggests that the impedances of the three branches of any node are equal, and that a current, I, flowing into a node through one branch flows out as I/2 through the other two branches. In other words, a current produced by closing a bit switch is cut by half as it passes through each node on the way to the end of the ladder. Simply speaking, the position of a switch, with respect to the point where the current is measured, determines the binary significance of the particular switch closure.

This type of converter is easy to manufacture because only two resistor types are needed and can be reduced to one value, R, if three components are used for each bit. Keeping matched resistor values with the same temperature coefficients contributes to a very stable design. Certain tradeoffs are required between ladder resistance values and current flow to balance accuracy and noise.

One form of the R–2R ladder digital to analog converter is the multiplying digital to analog converter. Digital to analog converters are available with either a fixed reference or with an external variable reference. Multiplying digital to analog converters, which utilize external variable analog references, produce outputs which are directly proportional to the product of the digital input multiplied by this variable reference. Functionally, these converters are available as current or voltage output types. The current output devices are necessarily faster because they do not include output amplifiers which limit the bandwidth. Because this output amplifier is not included, current digital to analog converters tend to be a little less expensive than voltage types.

Probably one of the most useful and cost effective multiplying digital to analog

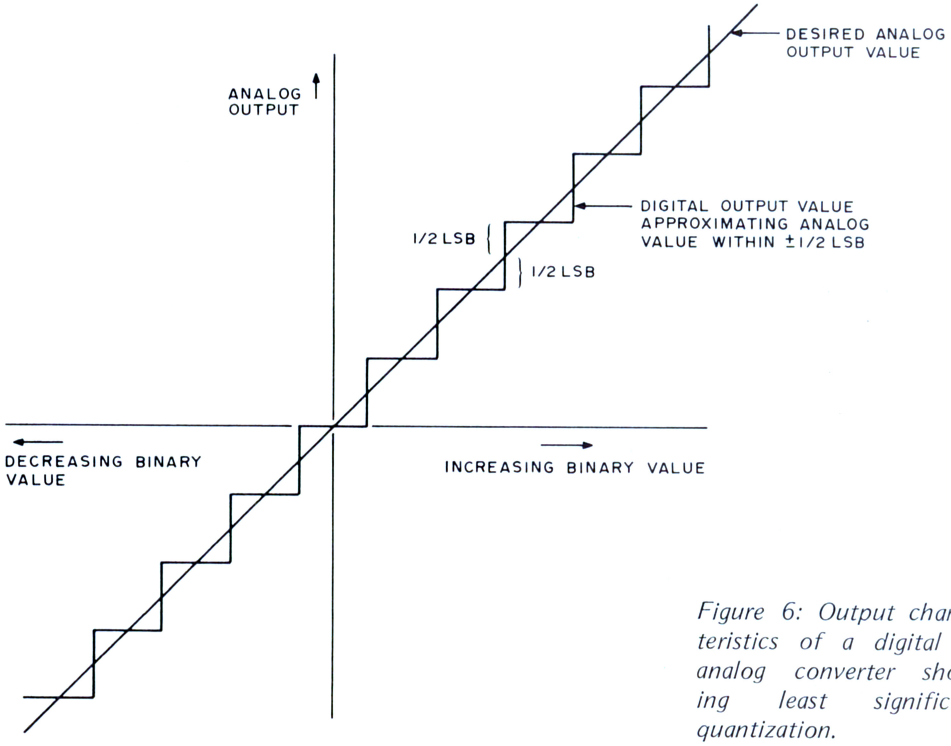
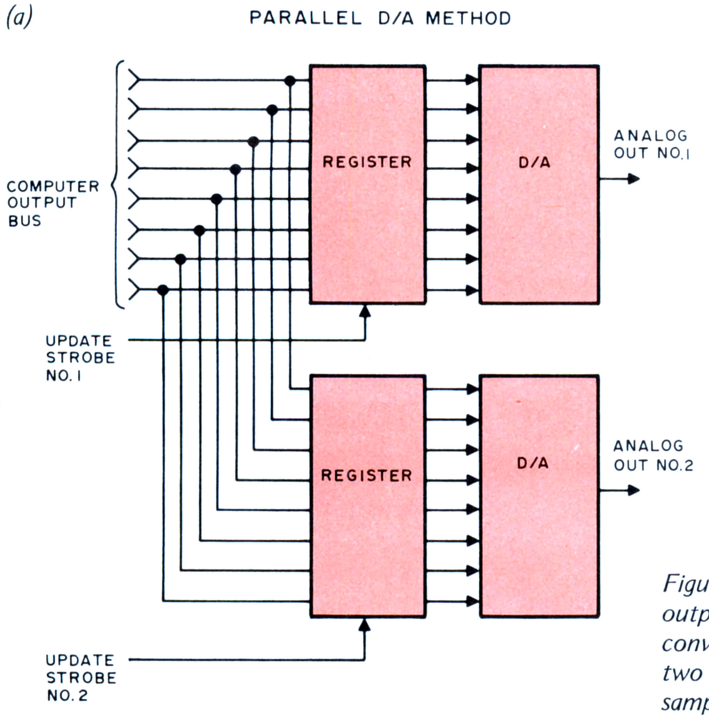
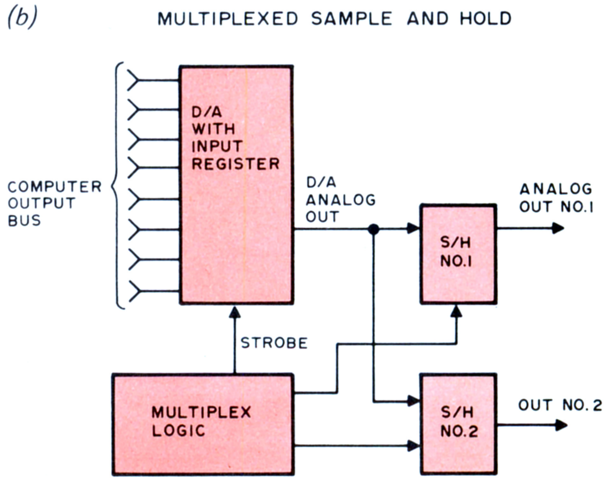


Figure 6: Output characteristics of a digital to analog converter showing least significant quantization.





Figures 7a and 7b: Two methods for providing multiple channel output capability. Figure 7a shows a parallel digital to analog converter method in which the computer routes information to two different digital to analog converters. In figure 7b, two sample and hold circuits are fed by the same digital to analog converter. Multiplex logic switches the output of the converter between the two sample and hold circuits. The latter do just what their name implies: when strobed, they store the value of the incoming voltage and stay very close to that value until strobed again, at which time they change to the new value. The sample and hold technique of figure 7b is economically more attractive than the multiple digital to analog converter approach.

converters available on the hobby market today is the Motorola MC1408L-8 8 bit digital to analog converter (see figures 5 and 6).

As previously mentioned, this monolithic converter contains an R–2R ladder network and current switching logic. Each binary bit controls a switch which regulates the current flowing through the ladder. If an 8 bit digital input of 11000000 (192_{10}) is applied to the control lines of the illustrated converter, the output current would be equal to (192/256) (2 mA) or 1.50 mA. Note that when binary 11 111 111 (or 255 decimal) is applied, there is always a remainder current which is equal to the least significant bit. This current is shunted to ground, and the maximum output current is 255/256 of the reference amplifier current, or 1.992 mA for a 2.0 mA reference current. The relative accuracy for the MC1408-L8 version is ±1/2 least significant bit, or 0.19% of full scale, and is more than adequate for most home computer analog control applications.

A Design with the User in Mind

I could actually stop right now and be satisfied that the reader has at least some idea of what a digital to analog converter is, but no mention has been made as to its uses. BYTE has published previous articles on digital to analog converters, but few actually using them in detail designs.

When we last left Ned in the testing lab, he was hooking up a voltage controlled pressure regulator and attaching it to the computer through a digital to analog interface. Though only the voltage requirement of the value was mentioned, the pressure detector is situated in an environmental control chamber with the temperature maintained by a setpoint controller.

At various times during the testing phase, the temperature is elevated. To adequately automate this test procedure, therefore, two analog output values are required: one for temperature setpoint and the other for pressure setpoint. It takes one digital to analog converter for the first voltage and we could add another separate digital to analog converter for the second voltage, but this is overly expensive and not necessary. The preferred method is to use multiplexed digital to analog conversion. This technique uses a single converter and switches it back and forth between the two channels doing the respective digital to analog conversion 50% of the time on each channel. To insure that each channel does not go on and off as the converter switches back and forth between them, a circuit called a sample and hold is employed on each channel to maintain the output at a constant level until the next refresh by the digital to analog converter. Figures 7a and 7b illustrate the

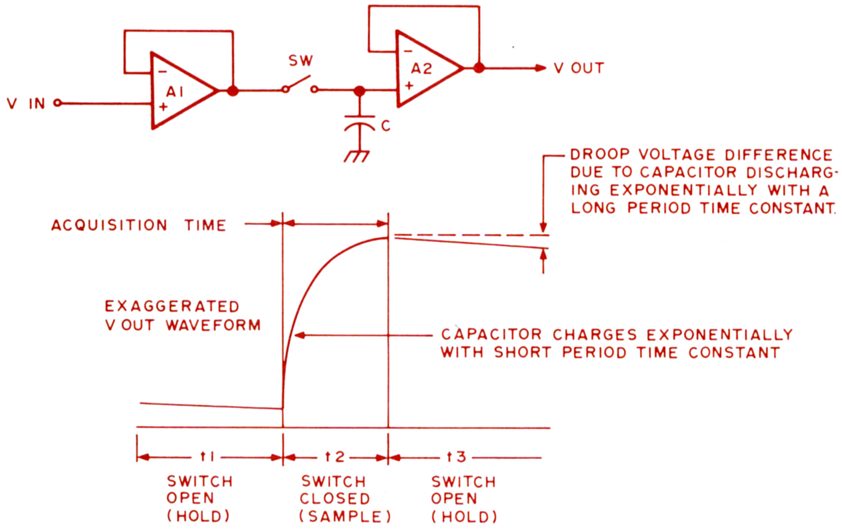

V IN
A1
SW
A2
C
V OUT
DROOP VOLTAGE DIFFERENCE DUE TO CAPACITOR DISCHARGING EXPONENTIALLY WITH A LONG PERIOD TIME CONSTANT.
ACQUISITION TIME
EXAGGERATED V OUT WAVEFORM
CAPACITOR CHARGES EXPONENTIALLY WITH SHORT PERIOD TIME CONSTANT
t1
t2
t3
SWITCH OPEN (HOLD)
SWITCH CLOSED (SAMPLE)
SWITCH OPEN (HOLD)

Figure 8: A basic sample and hold circuit. When the switch is closed, the capacitor begins to charge up exponentially to the value of the input voltage. Theoretically, the capacitor will maintain this value indefinitely after the switch is opened, but in reality a certain amount of voltage "droop" (exponential decay) will occur over time as the capacitor slowly discharges.

separator versus multiplexed digital to analog approach, and figure 8 illustrates a basic sample and hold circuit.

A sample and hold circuit is simply a charged capacitor analog storage device. Amplifier A1 is an impedance isolating buffer connected to the digital to analog converter or other voltage supply and connected to the capacitor through a switch. This switch is normally open in the "hold" state. When the output is to be updated, the switch is closed, the circuit enters the "sample" or acquisition mode, causing the capacitor to charge exponentially toward the new value present at the output of A1. When the switch is reopened and again in the "hold" state, the output of A2 will be equal to the capacitor voltage level.

The secret of good sample and hold is to use good high input impedance buffers to minimize the leakage from the capacitor and hold the output for long periods of time. No sample and hold can be designed without some droop during the holding period. The best that the designer can do to minimize this feature is to use precision components (usually more expensive) and refresh the sample and hold frequently enough to overcome decay problems.

Is There a Way to Overcome the Necessity to Refresh Sample and Hold Outputs?

For the home computer experimenter, sample and hold outputs, which require periodic refreshing, can become a bother. This is especially true during step-by-step checkout of system software.

Refreshing a multiplexed digital to analog interface usually requires a separate digital to analog refresh subroutine which must be called at regular intervals while executing the program. Simple, inexpensive sample and holds may require updating tens of times per second, while the better designed circuits available to the hobbyist can do satisfactorily with a once per second update. The fact remains, though, that the refresh is a requirement. This can limit digital to analog interface applications.

Drive the Digital to Analog Converter with BASIC?

Many extended BASIC programs such as the Digital Group MaxiBASIC can directly interface with computer input and output ports. This means that analog devices can be driven with a digital to analog converter, analog data processed through an analog to digital converter, and the acquired data mathematically manipulated using BASIC. The implication is a pseudoreal time analog control scheme utilizing BASIC. This is a realistic capability in slow process control applications where control feedback does not have to be activated within microseconds of an initiating event. Solar heating, low duty cycle repetitive machine functions, building environmental control systems, and supervisory control of setpoint controllers are examples of slow processes where slow computer response is of no major consequence.

The Final Configuration

Utilization of BASIC as a real time operating system does imply some constraints. If analog control is involved, the time between updates to an analog output interface can be on the order of tens of seconds, especially if the computer is required to do extensive calculations and record outputs to a printer. Of course, a special interrupt driver could be added to the BASIC and the processor interrupted frequently to service the external devices; but why make life difficult? The idea of using BASIC in the first place was to provide a control capability without adding special machine language drivers, a capability which would enable anyone to try his or her hand at closed loop control programming. This approach, though, tends to eliminate the classical sample and hold multichannel digital to analog method from consideration. It would also seem that the only approach left is the separate storage register and

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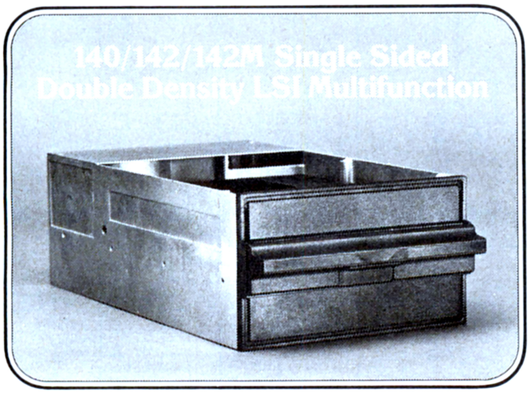
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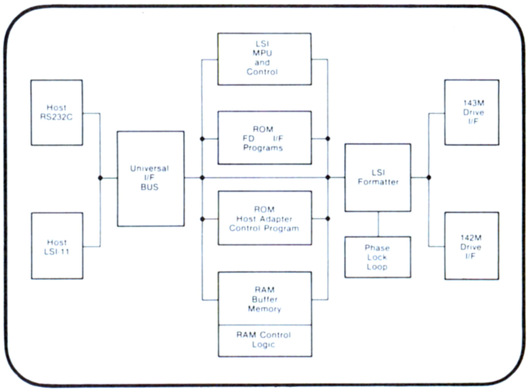
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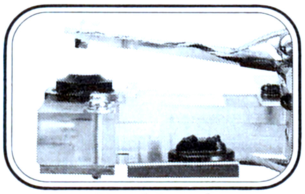

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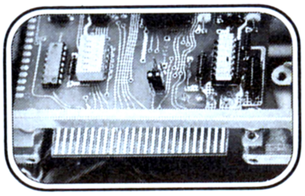

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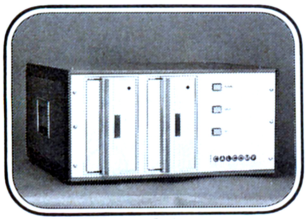

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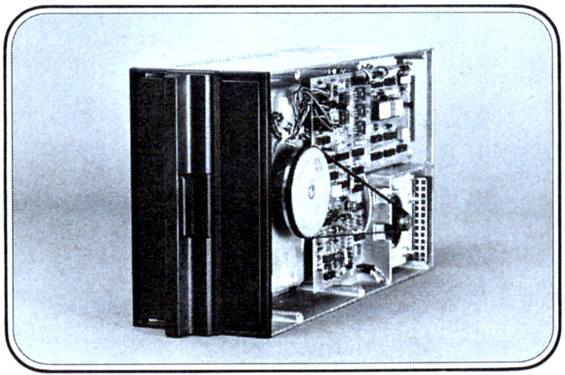

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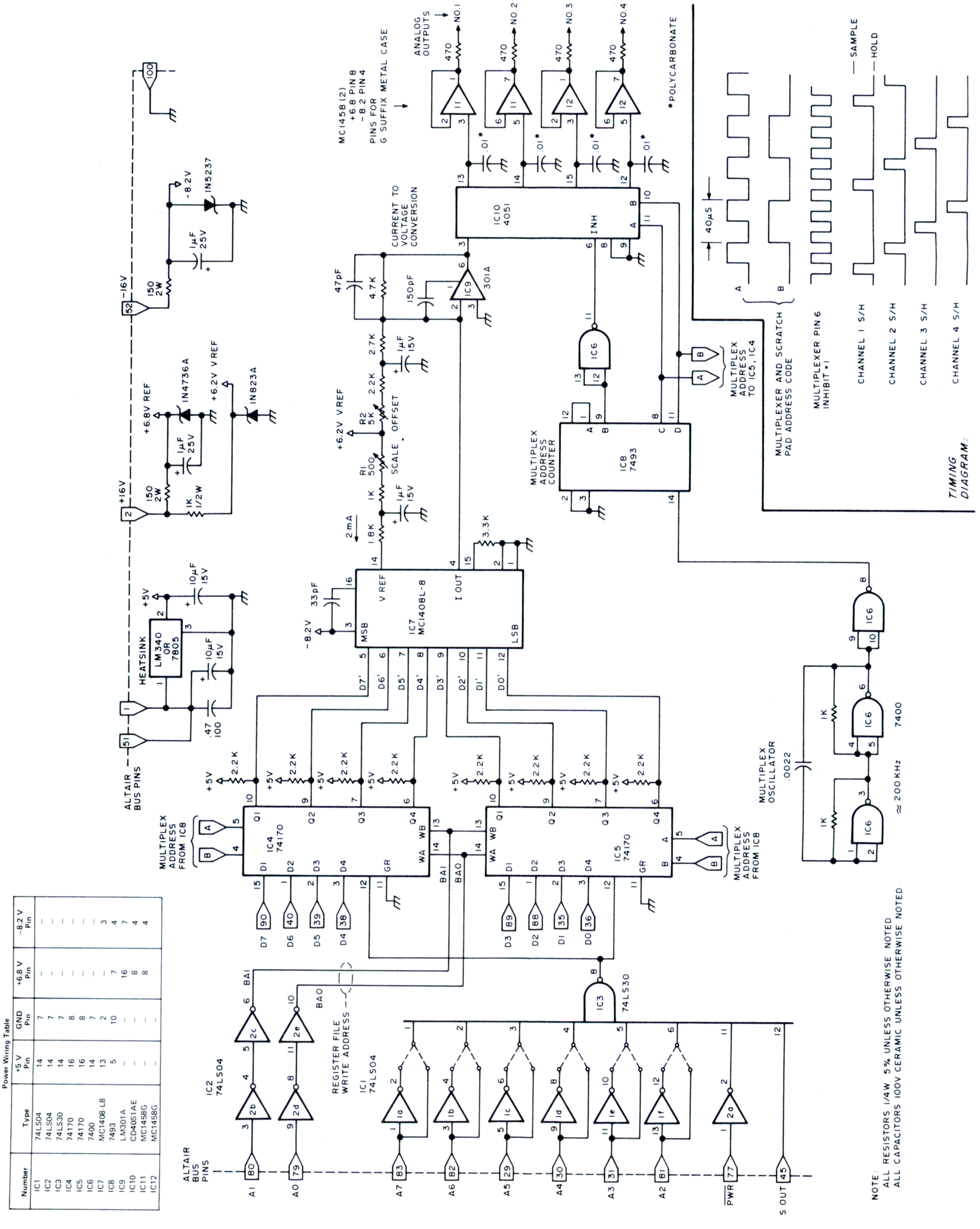
Figure 9: A "smart" 4 channel self-refreshing digital to analog converter. The circuit is self-refreshing and asynchronous in the sense that it maintains its analog outputs independent of computer timing. IC1, IC2 and IC3 form an address decoding network which decodes the 8080 or Z-80 processor's output port address and strobes the computer data bus contents into IC4 and IC5,


ANALOG OUTPUTS
NO. 1
NO. 2
NO. 3
NO. 4
470
*POLYCARBONATE
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MC1458(2) +6.8 PIN 8 -8.2 PIN 4 PINS FOR G SUFFIX METAL CASE
IC11
IC12
IC10 4051
INH
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IC9 301A
47pF
4.7K
150pF
2.7K
2.2K
1µF 15V
R2 5K OFFSET
R1 500 SCALE
+6.2V VREF
1K
1.8K
2mA
3.3K
33pF
-8.2V
IC7 MC1408L-8
V REF
I OUT
MSB
LSB
D7' D6' D5' D4' D3' D2' D1' D0'
MULTIPLEX ADDRESS COUNTER
IC8 7493
MULTIPLEX ADDRESS TO IC5, IC4
MULTIPLEX OSCILLATOR
.0022
≈ 200KHz
IC6
7400
+5V
2.2K
IC4 74170
IC5 74170
WA WB GR
BA1 BA0
MULTIPLEX ADDRESS FROM IC8
D7 D6 D5 D4 D3 D2 D1 D0
IC3 74LS30
IC2 74LS04
IC1 74LS04
REGISTER FILE WRITE ADDRESS
ALTAIR BUS PINS
A1 A0 A7 A6 A5 A4 A3 A2 PWR S OUT
HEATSINK
LM340 OR 7805
10µF 15V
.47 100
+16V
150 2W
1K 1/2W
1µF 25V
+6.8V REF
1N4736A
+6.2V VREF
1N823A
-16V
-8.2V
1N5237
40µS
A
B
MULTIPLEXER AND SCRATCH PAD ADDRESS CODE
MULTIPLEXER PIN 6 INHIBIT = 1
CHANNEL 1 S/H
CHANNEL 2 S/H
CHANNEL 3 S/H
CHANNEL 4 S/H
SAMPLE
HOLD
TIMING DIAGRAM

Power Wiring Table

Number	Type	+5 V Pin	GND Pin	+6.8 V Pin	-8.2 V Pin
IC1	74LS04	14	7	–	–
IC2	74LS04	14	7	–	–
IC3	74LS30	14	7	–	–
IC4	74170	16	8	–	–
IC5	74170	16	8	–	–
IC6	7400	14	7	–	–
IC7	MC1408-L8	13	2	–	3
IC8	7493	5	10	7	4
IC9	LM301A	–	–	16	7
IC10	CD4051AE	–	–	8	4
IC11	MC1458G	–	–	8	4
IC12	MC1458G	–	–		

NOTE:
ALL RESISTORS 1/4W 5% UNLESS OTHERWISE NOTED
ALL CAPACITORS 100V CERAMIC UNLESS OTHERWISE NOTED

which form an 8 bit random access scratch pad. IC7 performs the actual analog to digital conversion. The remaining portion of the circuit consists of timing generation and an analog multiplexer with sample and hold circuitry.

digital to analog converter combination previously illustrated. A more intelligent alternative is a combination of the two methods.

The necessary interface is essentially a smart multiplexed digital to analog converter which maintains its analog setpoints independent of the computer timing. The design of this interface is illustrated in figure 9. It is a hybrid system composed of separate digital storage sample and hold circuits for each of four output channels. Internal timing generators sequentially read the storage registers, initiate the digital to analog conversion, and refresh the sample and holds. Photo 1 shows how this card looks when built using a Vector board with 44 pin edge connector.

The key feature of this unit is the input storage buffer. Two 74170 4 by 4 bit registers are configured to form a 4 word by 8 bit random access scratch pad. An address decoding network composed of IC1, IC2, and IC3 decodes the processor's output port address and strobes the computer data bus contents into the appropriate scratch pad location. These four jumper selectable port addresses can be set to be any four consecutively numbered output ports. The exact selection and jumpering details are outlined in the check out procedure. This particular scratch pad can be written into and read from simultaneously. The interface is completely asynchronous and does not have to be synchronized with the computer in any way.

There are four basic sections to the interface: the scratch pad and port decoding, digital to analog converter, timing generator and analog multiplexer, and sample and holds. A basic timing diagram of the interface is illustrated as part of figure 9.

The timing section consists of a 200 kHz clock generator IC6 and address counter IC8. The 7493 counts down the 200 kHz clock and drives the address lines of the scratch pad and multiplexer at a 50 kHz conversion rate. Each channel is accessed, converted and sampled in a similar manner. When the address lines have settled on a particular channel, the output lines of the scratch pad (IC4 and IC5) present the respective stored digital word to the digital to analog converter IC7. The converter immediately starts moving towards the new value.

Since its settling time is dependent upon the magnitude of change from one channel to the next, the worst case being minus full scale to plus full scale, the 20 μs conversion period incorporates a 10 μs settling time. For the first 10 μs, the analog multiplexer IC10 is inhibited from conducting the signal to the sample and hold. After this settling time has concluded, the inhibit signal is dropped, and for the next 10 μs the sample and hold for that particular channel is in the sample mode. The circuit automatically sequences itself to the next scratch pad address and repeats the process over and over.

Anyone capable of a little quick math can realize that if the digital to analog conversion is proceeding at 50,000 conversions a second, each sample and hold is being updated at the fantastic rate of 12,500 times a second. This seems to be in direct disagreement with a "tens of times a second" statement made earlier. It is important to remember that this is an asynchronous analog interface. When new data is written into the scratch pad, the new value is not available at the sample and hold output until the next regular sampling period, controlled by the timing generator. The high sampling rate is more to increase the response of the interface than refresh the outputs.

At a 50 kHz conversion frequency, there is a worst case delay of 80 μs between a scratch pad update and an appropriate analog output response. This is of no consequence as far as this article is concerned. However, to maintain the ability to use BASIC as a real time operating system and yet not lose the capability to do high speed applications such as voice synthesis, a few simple modifications can be made. The interface clock rate can be increased from 200 kHz to 400 kHz. This has been successfully accomplished on the prototype and will increase the sampling rate on each channel to 25,000 samples per second. Unfortunately, it is far more demanding of the current to voltage converter IC9. Only one out of three LM301As may work successfully over the full range of 10 V. Another quick method is to remove the 7493 (IC8). This causes the interface to stay addressed on channel 4, doing 50,000 uninhibited conversions per second.

The converter itself is an 8 bit MC1408L-8 multiplying digital to analog converter. As previously outlined, "multiplying" means that it uses an external variable reference voltage. In this case, a 6.8 V zener diode regulated voltage is passed

Continued on page 156

Expanding the Tiny Assembler

(Increasing Function without Building More Memory)

Jack Emmerichs
8465 N 51
Brown Deer WI 53223

```
LOCN B1 B2 B3

0000           >************************************************
0000           >*                                               *
0000           >*        EXAMPLE OF AN INLINE BGN BLOCK         *
0000           >*                                               *
0000           >************************************************
0100           >         ORG  $100
0100           >ROUTINEA RMB  2        SUBROUTINES AVAILABLE
0102           >ROUTINEB RMB  2          IN EXISTING CODE
0104           >ROUTINEC RMB  2
0106           >ROUTINED RMB  2
0108           >ROUTINEE RMB  2
010A           >ROUTINEF RMB  2
010C           >FLAG1    RMB  1        TEST CONDITIONS
010D           >FLAG2    RMB  1          AVAILABLE IN
010E           >FLAG3    RMB  1          EXISTING CODE
0200           >         ORG  $200
0200           >************************************************
0200           >*                   INLINE CODE                 *
0200           >************************************************
0200           >
0200           >NEWBLOCK BGN           START OF INLINE BLOCK
0200 7D 01 0C  >         TST  FLAG1
0203 2D 00     >         BLT  COND1    JUMP TO SUBROUTINE
0205 22 00     >         BHI  COND2      DEPENDING ON TEST
0207 7D 01 0D  >         TST  FLAG2      CONDITIONS
020A 23 00     >         BLS  COND3
020C BD 01 00  >         JSR  ROUTINEA
020F 20 00     >         BRA  GO       FIRST USE OF SYMBOL 'GO'
0211 BD 01 02  >COND1    JSR  ROUTINEB
0204 0C
0214 20 00     >         BRA  GO
0216 BD 01 04  >COND2    JSR  ROUTINEC
0206 0F
0219 20 00     >         BRA  GO
021B BD 01 06  >COND3    JSR  ROUTINED
020B 0F
021E BD 01 08  >GO       JSR  ROUTINEE  SYMBOL 'GO' RESOLVED
0215 08
021A 03
0210 0D
0221           >         END           END OF INLINE BLOCK
*** UNRESOLVED:
*** SYMBOLS?
Y
CON1 0211  CON2 0216  CON3 021B  GO   021E

0221
0221 7D 01 0E  >CONTINUE TST  FLAG3
0224 22 00     >         BHI  GO       REUSE OF SYMBOL 'GO'
0226 BD 01 0A  >         JSR  ROUTINEF
0229 01        >GO       NOP           'GO' RESOLVED AGAIN
0225 03
022A           >************************************************
022A           >*               INLINE CODE CONTINUES           *
022A           >************************************************
022A           >
022A           >         END           END OF ASSEMBLY
*** UNRESOLVED:
*** SYMBOLS?
Y
CONE 0221  FLA1 010C  FLA2 010D  FLA3 010E  GO   0229
NEWK 0200  ROUA 0100  ROUB 0102  ROUC 0104  ROUD 0106
ROUE 0108  ROUF 010A


*
```

Listing 1: This simple in line BGN block shows the format of the BGN and END pseudooperations of the Version 3.1 Tiny Assembler. Any symbols defined within the block are deleted by the END statement for the block and can be reused without conflict by subsequent code. Thus the symbol GO at location 021E defined within block NEWBLOCK is not the same location as the later use of GO in the outer level of the hierarchy at location 0229. Note that the new version of Tiny Assembler still condenses symbols into 4 character names in the symbol table by using the first three and the last characters of the symbol as typed. Thus the NEWBLOCK name at location 200 condenses to NEWK in the symbol table.

It is worth noting that the group of people who have been using the Tiny Assembler since the end of 1976 as listed on page 133 of the March 1977 BYTE excludes the author: ME! Well, I have finally gotten my own computer system up and running and have been able to get some use out of the assembler myself. I soon found that there were a few things here and a few things there that could be changed or added that would make the whole assembly process more convenient. I guess there is just no pleasing some people.

The problem is that, as predicted, I have a minimal configuration system. It is a SwTPC 6800 with (at the moment) no extras. The assembler just fits, so there is no place to put patches or additions except at the top of the symbol table. This of course reduces the capacity of the program. It became obvious that the proper approach to further modifications would be to increase the efficiency of the assembler so that additions could be made while maintaining or increasing the symbol table capacity. The first modification, therefore, would have to be the ability to delete symbols when no longer needed so that the symbol table space could be reused. This would allow a smaller table to handle a larger number of symbols.

As suggested in the article "Implementing the Tiny Assembler" (May 1977 BYTE, page 84), this has been accomplished by developing a "begin" statement (the assembler mnemonic is BGN). This statement causes the next available location in the symbol table to be pushed into a table stack and a structural level counter (which starts at 1 and keeps track of the nesting level of the BGN statements) to be incremented. Symbols entered beyond this point in the table belong to this BGN block. A label on the BGN statement itself will not belong to the block being defined, but to the group of symbols already in the table. The END statement must then be changed to pull a symbol table location out of the table stack and perform end of block processing on the symbols from this point to the end of the table. Everything relating to these symbols is then cleared from the assembler's tables. The structural level indicator is decremented, and if it becomes 0, end of program is signaled. Using this arrangement, the nesting level of BGN blocks is only limited by the space available for the table stack or the size of the structural level counter (256 in this case).

In practice, the BGN block is used to break a program into individual segments that can each be treated as single functions or routines. Labels and variable names within such blocks are local to the block and are not known outside the block in the rest of the program. This can be most useful when employing structured programming techniques such as those that have appeared from time to time in BYTE articles. A properly structured BGN block should have only one entry point and one exit point. It may be used in either of two different ways.

First, a section of in line code that is only used in one place in a program may be defined as a structural block. Such a block is entered by "falling into" the first statement, and exited by "falling out of" the last statement as program steps are executed in sequential order. There will usually be no label associated with the BGN statement for such a block.

The second possibility is to define a block as a subroutine which can be called from one or more places in the program. Such a block is entered by a jump or branch to subroutine and is exited by a return statement. In this case the entry point (which is usually the BGN statement itself) does require a label. In both cases, once a block has been completed, the internal structure is of no interest to the rest of the program, and any entries in the symbol table and the forward reference table for the current block may be removed when the block is ended.

An example of a small in line BGN block is shown in listing 1. Once this group of branch and jump instructions has been completed, the symbols defined within it may be reused without conflict. A more complex program structure using BGN blocks as subroutines is shown in figure 1. This is similar to the hierarchy diagrams discussed in the first of these articles (see "Designing the Tiny Assembler," April 1977 BYTE, page 84, for a discussion of hierarchies and networks). The pseudocode to implement this structure is shown in listing 2. Within any block, references can be made to entries in the symbol table for any already active block (ancestors), the entry point of any block at the same level (siblings), the entry point of any block at the next lower level (direct descendants), and the entry point of any block which is at the same level as currently active ancestor blocks (aunts and uncles). References cannot be made to items which are across any level of siblings and then down another branch of the "family tree" (nieces, nephews and cousins), or to items developed within a lower level of the tree. This is a fairly standard structuring scheme.

Listing 2: This is a structured pseudocode representation which shows how the hierarchy of figure 1 would be implemented in a normal coding sequence. The assembly starts with an initial (outer or global is an equivalent term) level so there is one more END statement than the number of BGN statements. This is required to finally terminate the assembly. In this listing, indentation of the code has been used to highlight the various levels of nesting of the blocks from figure 1.

```
START OF PROGRAM (level A)
:    BGN (level B)
:    :    BGN (level C)
:    :    END
:    :    BGN (level D)
:    :    END
:    END
:    BGN (level E)
:    :    BGN (level F)
:    :    END
:    :    BGN (level G)
:    :    :    BGN (level H)
:    :    :    END
:    :    :    BGN (level I)
:    :    :    :    BGN (level J)
:    :    :    :    END
:    :    :    :    BGN (level K)
:    :    :    :    END
:    :    :    END
:    :    END
:    END
:    BGN (level L)
:    END
END (end of assembly)
```

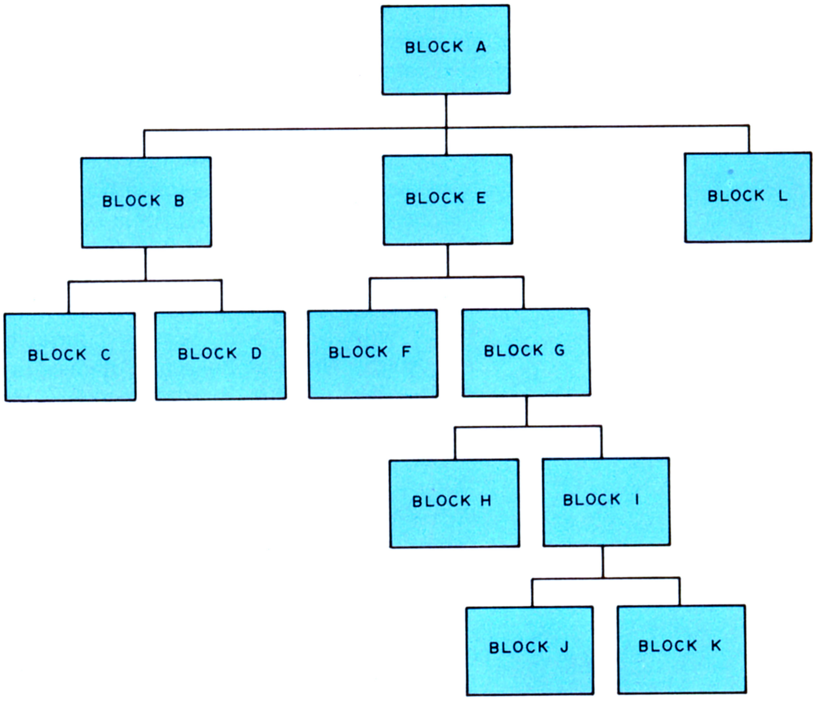

Figure 1: This hierarchy diagram shows the relationships between the functional blocks used in the example of listing 2. Of the 12 blocks in the system of this program, only a maximum of five are ever active and using up space in the symbol table at any one time. Any entry point referenced at the beginning of block A during the 1 pass assembler's operation is available to any block in the hierarchy even if it is not defined until the end of the assembly.

This general arrangement is significantly modified, however, by the 1 pass nature of the Tiny Assembler. In this case, a symbol "belongs to" the first block that references it rather than the block that defines it as a label. Therefore, a symbol that is defined and used at a low level is inaccessible to higher levels as usual, but symbols that are first referenced in a low level block of code and then defined as a label in a later higher level block of code cannot be handled by the assembler. This is because the symbol belongs to the low level block, and both the forward reference table and the symbol table will be cleared of all references to such a symbol at the end of the low level block.

This problem of what level the symbol belongs to can be avoided by requiring such symbols to be first entered into the symbol table by a high level block of code (as a forward reference if need be). In this way the symbol and all references to it will belong to the high level block and will stay in the tables while low level blocks are created and ended. When the symbol is finally used as a label, all unresolved references to it will be resolved, even those which were made in blocks which have been terminated and no longer exist. In general, a symbol must be entered into the symbol table at a level equal to or higher than every reference that is made to it. It is therefore a good idea to define common subroutines early in the program or to make reference to their entry point names in the highest levels of the structure.

To illustrate how these rules are applied, consider what symbols are "known to," or can be referenced by code within block G in the example in figure 1. Any items in A and E that have already been used can be referenced because they are ancestors. Any items within G itself can of course be referenced. This was the scope of the original versions of the Tiny Assembler. The entry points of H and I can be referenced because they are direct descendants. The entry point of B can be referenced because it is an ancestor's sibling that has already been defined. The entry point of F can be referenced because it is a sibling that has already been defined. Any items first used within H, I, J or K cannot be referenced by G because they belong to a lower level. Any information about C and D that was not originally referenced in A is unavailable because they are cousins. The entry point of L (if not yet used) and any items in A and E that have not yet been used cannot be made a forward reference because they will not be defined until after references to them from G have been removed.

When a program is structured as a network instead of a simple hierarchy, things become a bit more complex because of relationships that cross between branches of the structural tree. The same rules apply when determining what can be referenced from what, however, so a program's block structure should be planned so that multiple paths within the network can be contained within a single block to reduce or eliminate forward reference problems.

For programs with a moderate number of symbols or extremely complex forward references, the whole assembly may be considered a single block. In this case, no BGN statement need be used at all. The first END statement that is encountered ends the program much as it does in the original versions of the Tiny Assembler.

It should be pointed out that the entire table of currently active symbols is searched during symbol processing. Therefore, a block may not redefine a symbol used by an earlier but still active block. If this is tried, a duplicate symbol error will occur. This restriction is based on the fact that a 1 pass assembler allowing redefinition of symbols at a local level could not tell the difference between a forward reference to a redefined local symbol and a backward reference to an existing global symbol. Therefore, symbols may only be reused after they have been deleted from the symbol table by an END statement. As it turns out, the hierarchical structuring scheme of the Tiny Assembler is similar to other structural languages such as PL/I, but the restrictions on redefining symbols and the rules determining what level of the structure a symbol belongs to make the structuring of source programs for this assembler unique.

While developing the methods used to handle BGN and END statements it became evident that the deletion and possible reuse of symbols would make it very difficult to produce a complete symbol table dump at the end of the program. In fact, there may never be a complete symbol table during an entire assembly (a situation which requires a 1 pass design by the way). Therefore, each END statement terminates a structural block as if it were a complete program. All unresolved forward references to symbols first used in the current block are listed and the user is given a chance to abort the END statement. If it is aborted, the user will reenter the block, and may continue with corrections and additions as if the END had not been entered. If the user does not elect to abort the END statement, a sorted symbol table listing is provided for the completed block. In this way, every

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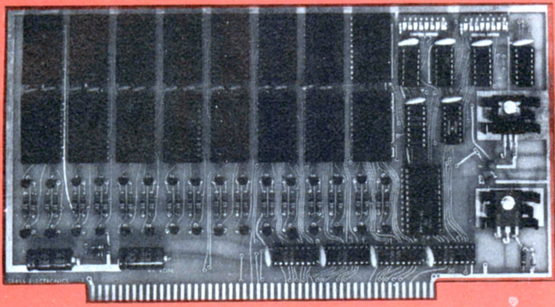

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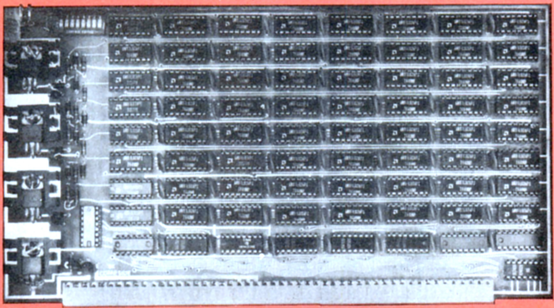

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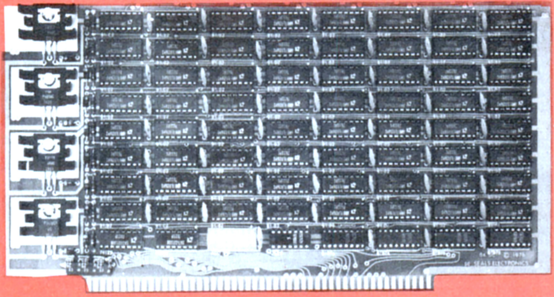

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TELEX NO. 55-7444 TELEPHONE NO. 615/693-8655 occurrence of every symbol and unresolved reference in an assembly is listed without requiring that they ever really exist at the same time.

Does this "virtual symbol table" mean that we have an assembler of unlimited capacity that will run in 4 K? Well, no, not really. While this may be theoretically true, there are some practical limits which are likely to be reached. All programs have a root segment and a list of global symbols which exist throughout the entire assembly. As the program increases in size, the root segment usually grows along with it, but at a slower rate. At some point it becomes impractical to try to fit ever larger programs into the Tiny Assembler. The current design provides for 150 symbols when running in a 4 K machine. This is large enough to assemble simple programs with ease, significant programs through moderate use of structural blocking, and large complex programs if need be. I don't really know what its practical limit would be now, because as noted earlier, I haven't really used the Tiny Assembler enough.

```
G


LOCN B1 B2 B3

0000          >*******************************************************
0000          >*                                                      *
0000          >*   EXAMPLES OF THE EXTENDED TINY ASSEMBLER FUNCTIONS   *
0000          >*                                                      *
0000          >*******************************************************
0000          >
0000 41 42 43 >          FCC  5,ABCDE   STRING LENGTH = 5
0003 44 45
0005 41 42 43 >          FCC  /ABCDE/   STRING DELIMITERS CAN BE ANY
0008 44 45
000A 41 42 43 >          FCC  ;ABCDE;     NON NUMERIC VALID CHARACTER
000D 44 45
000F          >
000F 31 32 00 >          FCB  '1,'2,WW  USE OF APOSTROPHE IN FCB AND
0012 00 00    >          FDB  XX          FORWARD REFERENCE IN FCB & FDB
0014          >
0003          >WW        EQU  3         RESOLVE FORWARD REFERENCES IN
0011 03
1FFF          >XX        EQU  $1FFF       PREVIOUS FCB & FDB
0012 1F FF
0014          >
0014 2C 27 20 >          FCB  ',,'',' ,'+
0017 2B
0018          >*                        NOTE USE OF COMMA AS A LITERAL
0018          >*                          AND AS A DELIMITER ABOVE
0018          >
0100          >CONTINUE ORG  $100       FULL FUNCTION ORG STATEMENT
0100 01 00    >          FDB  CONTINUE
0102          >*PAGE



LOCN B1 B2 B3

0102          >*******************************************************
0102          >*          EXAMPLE OF FORWARD REFERENCE HANDLING        *
0102          >*******************************************************
0102          >
0102          >FWDREF   BGN            START NEW STRUCTURAL BLOCK
0102 B6 00 00 >         LDAA AAAA      ESTABLISH FORWARD REFERENCES
0105 B6 00 00 >         LDAA BBBB
0108          >
0108          >NXTLEVEL BGN            START ANOTHER STRUCTURAL BLOCK
0108 B6 00 00 >         LDAA AAAA      REFERENCE ALREADY ESTABLISHED
010B B6 00 00 >         LDAA BBBB      BBBB ALSO ESTABLISHED
010E B6 00 00 >         LDAA CCCC      REFERENCE TO NEW ITEM
0111          >         END            END OF NXTLEVEL, CCCC IS UNDEFINED
*** UNRESOLVED:
CCCC 010F
*** SYMBOLS?
Y
CCCC 0000

0111
00FF          >AAAA     EQU  $FF       RESOLVE SYMBOL AAAA
0103 00 FF
0109 00 FF
0111          >         END            END FWDREF
*** UNRESOLVED:
BBBB 0106
BBBB 010C
*** SYMBOLS?
N

0111
0001          >BBBB     EQU  1         ABORT END AND DEFINE BBBB
0106 00 01
010C 00 01
0111          >         END            END FWDREF AGAIN
*** UNRESOLVED:
*** SYMBOLS?
Y
AAAA 00FF   BBBB 0001   NXTL 0108

0111
0111          >         END            END OF ASSEMBLY
*** UNRESOLVED:
*** SYMBOLS?
Y
CONE 0100   FWDF 0102   WW   0003   XX   1FFF


*
```

Listing 3: In addition to the reorganization of symbol table management and introduction of the BGN pseudooperation, a number of minor incremental improvements were added to Version 3.1 of the assembler. These are illustrated here, and are described in more detail in the text of the article.

As an additional improvement, the Version 3.1 Tiny Assembler can now expand or contract to the user's requirements. If an 8 K machine were used, the symbol table could be increased to hold over 830 symbols. This could be effectively expanded into the thousands through the use of structural blocking. However, the sequential search times required to find symbols in such a table would no doubt start to become noticeable. Remember, this is supposed to be a TINY assembler, not competition for a full-scale standard assembler.

Having addressed the capacity problem, I then returned to the minor changes that started this whole modification project in the first place. Several items which did not work as one might expect in the previous version have been changed to process in a more normal manner, and a larger subset of the Motorola 6800 assembly language definition is now supported. The following is a list of some of the major changes which have been made. They are illustrated (where possible) in listing 3.

- The FCC pseudooperation will allow the use of character string delimiters as well as the previous string length operand.
- The FCB statement will allow the use of literals following an apostrophe, and the FCB and FDB statements may now make forward references.
- Delimiters such as the comma (,), space ( ), plus (+) and minus (–) may be used as literals after an apostrophe. The apostrophe itself may be used as such a literal.
- If a label is used with an ORG statement, its value (as well as the program counter) is set to the value of the operand.
- Execution of the assembler after an assembly has been completed invokes the cold start rather than the warm

start entry point so that different programs being assembled at the same time are completely separated. Within a given assembly, however, restarts are still from a warm start entry point. A warm start uses the old symbol table contents, and a cold start clears the entire symbol table before entry.

- The Tiny Assembler can now be stored in its entirety in ROM or PROM, and it is more easily relocatable.
- The forward reference and symbol tables can be redefined at a location and size determined by the user.
- A comment line starting with *P will produce a page break and a new heading (eg: *PAGE).

While modifying the assembler, I found the need for a simple, quiet (on a Teletype) loader to try out various program changes. As mentioned in previous articles, there are two types of loaders for the Tiny Assembler. Those handling complex forward references must first zero memory and then add each byte of generated code to the current memory value (a single memory location may have several components added to it). Those handling corrections made by the user when the assembler is used interactively must simply replace whatever is currently in memory with the generated code. Since I tend to have many more errors to correct than complex references to handle, the loader shown in listing 4 was developed to complement the one listed in the *Tiny Assembler User's Guide*. If the assembler's stack is relocated from A07F to A042 (which is easy to do: simply change locations 06D3, 06D4 of Version 3.1), the assembler and the loader can remain resident in a 4 K machine at the same time. The code:

```
LDAA    #$3C
STAA    $8007
```

will suppress the echo on input for any program using the standard Motorola MIKBUG input routines. In this case it allows the Teletype to read the Tiny Assembler load tape without having the print mechanism chattering away.

The current version (3.1) of the Tiny Assembler is quite a powerful assembly program which will operate within very tight memory restrictions. In larger machines this may mean more space can be made available for an input source buffer, monitor, editor, assembled object modules or other memory resident programs. In small machines it may mean the difference between being able to assemble anything at all or not.

Listing 4: A "quiet" loader is one which demurely purrs as it loads in from the reader of a Teletype, ignoring the noisy printer. This is a loader capable of residing in the Motorola MIKBUG program's scratch pad and loading object code from the Tiny Assembler. Note that there is no end of tape character, nor facilities for rereading the loader tape for verification, nor error handling outside of that provided by the Motorola MIKBUG monitor's routines.

```
*G


LOCN B1 B2 B3

0000             >*****************************************
0000             >*                                       *
0000             >*  'QUIET' LOADER FOR THE TINY ASSEMBLER *
0000             >*                                       *
0000             >*****************************************
0000             >
E055             >HEXIN    EQU  $E055    MIKBUG HEX BYTE IN
E047             >ADRIN    EQU  $E047    MIKBUG ADDRESS IN
E1AC             >CHARIN   EQU  $E1AC    MIKBUG CHARACTER IN
E1D1             >CHAROUT  EQU  $E1D1    MIKBUG CHARACTER OUT
0001             >START    EQU  1        START LOADING CHAR
0001             >STOP     EQU  1        STOP LOADING CHAR
0000             >
A048             >         ORG  $A048
A048 00 00       >         FDB  LOADER   LOAD STARTING ADDR
A04A 86 3C       >LOADER   LDAA #$3C     SUPPRESS ECHO FOR
A048 A0 4A
A04C B7 80 07 >            STAA $8007      INPUT
A04F 86 3E       >         LDAA #'>      PRINT 'READY MARK'
A051 BD E1 D1 >            JSR  CHAROUT
A054 BD E1 AC >SEARCH      JSR  CHARIN   SEARCH FOR START
A057 81 01       >         CMPA #START     OF BLOCK
A059 26 F9       >         BNE  SEARCH
A05B BD E0 47 >            JSR  ADRIN    GET LOADING ADDRESS
A05E BD E1 AC >LOOP        JSR  CHARIN   READ NEXT CHARACTER
A061 81 01       >         CMPA #STOP    IF STOP CODE THEN
A063 27 EF       >         BEQ  SEARCH     SEARCH FOR NXT BLOCK
A065 BD E0 55 >            JSR  HEXIN    ELSE READ HEX BYTE
A068 A7 00       >         STAA X          STORE IT
A06A 08          >         INX             INCREMENT ADDRESS
A06B 20 F1       >         BRA  LOOP       AND CONTINUE
A06D             >
A06D             >         END           END OF ASSEMBLY
*** UNRESOLVED:
*** SYMBOLS?
Y
ADRN E047  CHAN E1AC  CHAT E1D1  HEXN E055  LOAR A04A
LOOP A05E  SEAH A054  STAT 0001  STOP 0001


*
```

I should point out that the development of the Tiny Assembler was not a 1 person project, but rather a collective madness that infected quite a few individuals. Several sections of Version 3.1 reflect the ideas and work of Al Losoff, Chuck Bram and George Kuss. As the assembler evolves, I would like to hear from others who have found new and wonderful ways to improve, modify or adapt the program to different environments and requirements. By the way, I do not have the facilities to answer requests for copies of the Tiny Assembler. Contact BITS, 70 Main St, Peterborough NH 03458, for the PAPERBYTES™ edition of Tiny, or the Milwaukee Computer Store, 6916 W North Av, Milwaukee WI 53213, for an AC-30 cassette of the object code ($6).■

Editor's note: *As this article goes to press, Version 3.0 of Tiny Assembler 6800 is available as a 40 page book complete with user's guide, machine readable (bar code) object listing and complete assembly listing. The price of this book is $7 plus 35 cents postage and it may be ordered through BITS. In preparation as this article goes to press is the Version 3.1 supplement to the original book, which will contain documentation of these extensions, machine readable (bar code) object listing, a reprint of this article, and a complete Tiny Assembler 6800 Version 3.1 source listing. Write BITS at 70 Main St, Peterborough NH 03458.*

Recognition for Heuristics SpeechLab

A new star is born. The Heuristics voice input board for the Altair (S-100) bus is an interesting new option for personal computing enthusiasts. Now, for $250 one can add voice input to the computer.

The first thing I noticed about the Heuristics SpeechLab was the price, $250 in kit form, compared to huge sums for commercial equipment. After seeing a live demonstration at the Homebrew Computer Club in Palo Alto CA, I was convinced that the board worked. Horace Enea and John Reykjalin, the principle designers, demonstrated the recognition of three words after a single training. Horace would type in a word and then pronounce it. The computer then used about 64 bytes to store a template for the word, "Apple, banana, mango. . ." The crowd at Homebrew stood in amazement as the computer typed out the spoken words.

Three weeks later I had my own SpeechLab kit. Surprise number two. The two documentation manuals are an order of magnitude better than anything else I've seen produced by the personal computer industry.

Hardware Manual

The hardware manual contains the standard sections: introduction, assembly, and theory of operation; but, the pages are numbered, paragraphs are tied together and the manual is actually readable. Several useful appendices are also included: troubleshooting, test program, warranty, schematics, etc.

Laboratory Manual

"Now what are you going to do with it?" is a question frequently asked by friends of personal computer owners. With this kit the question is the answer. The Heuristics people seem to be trying to create a Renaissance environment for scientific inquiry. The laboratory manual is a successful attempt to tie the diverse field of computer speech analysis together in a coherent fashion. The manual is bound to become popular among researchers in the field of speech recognition. The work is probably the best text material presently available on the subject.

The manual consists of 270 pages. The main body of the text presents 35 exploratory experiments to thoroughly acquaint the user with the problems and techniques of speech recognition. A sampling of experiments are: confusion matrix, compression amplifier, fricative consonants, and area averaging. A complete listing and explanation of Li Chen Wang's Palo Alto Tiny BASIC is included. The BASIC has been modified with a "Speech" command to access the speech input board through a high level interface. Most of the experiments are centered around Tiny BASIC, a wise design decision that makes experimentation easy and interesting. The experiments are clearly presented and should be easy to perform for anybody who can program in BASIC.

Assembly

The printed circuit board is silk-screened. Components are sequentially numbered as they appear on the board, from left top to bottom right. The layout appears to be flawless; no jumper patches are needed. I completed the assembly in two 2 hour sessions. Everything went smoothly except for two missing resistors which were supplied in four working days by mail. Like most small companies headed for success, Heuristics is bending over backwards to please customers. The hardware worked perfectly, so I didn't need the excellent troubleshooting section that is included.

One word of warning. The Heuristics board is intended for use with an Altair (S-100) bus 8080 computer, enough memory to run Tiny BASIC, and some application programs. A hardcopy terminal is not a must, but is useful for obtaining plots of waveforms.

Rick Parfitt
1 Johnstone Dr
San Francisco CA 94131

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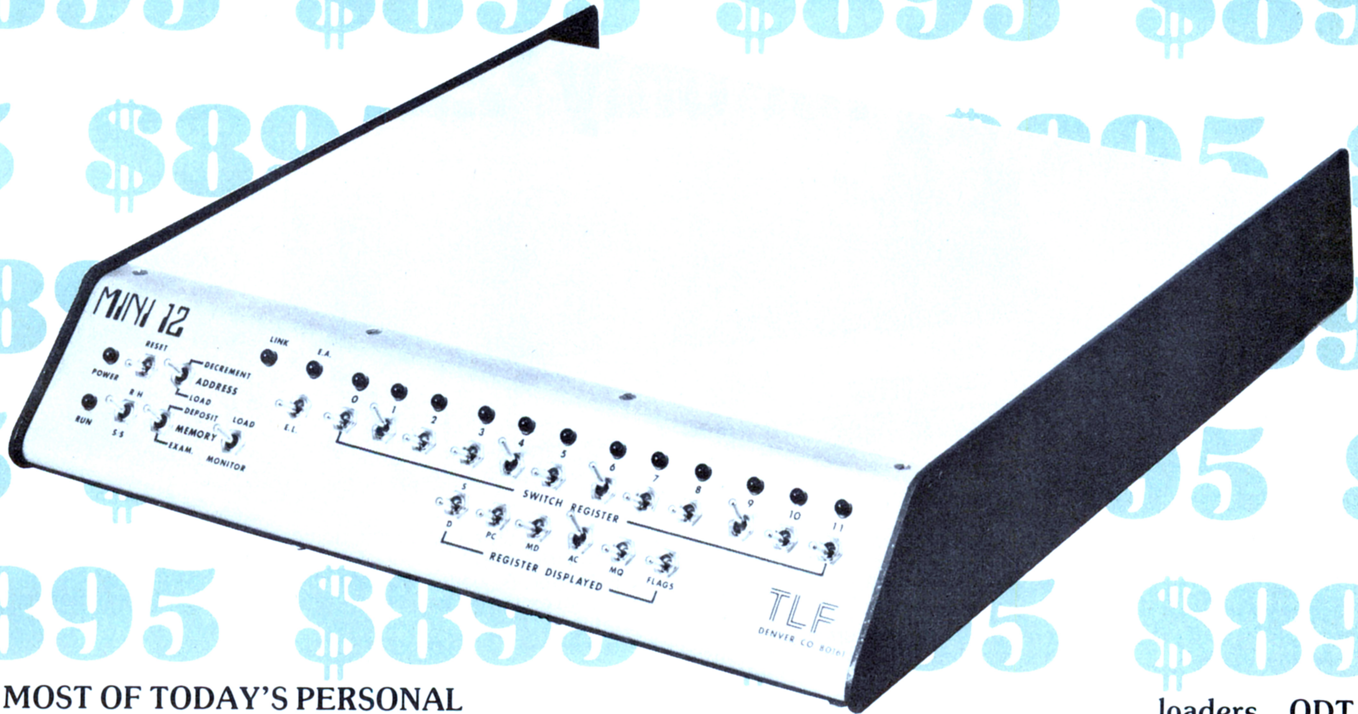

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The Model 500 is offered here in three forms to meet every application and pocket book.

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8″ x 10″ fully assembled board including 6502 microprocessor running at 1MHz, 512 bytes of PROM, 8192 bytes of ROM containing 8K BASIC and 4096 bytes of RAM for user programs. The board contains an ACIA based serial interface which is jumper selectable for RS-232C or 20ma loop at 110, 300, 1200, 2400, or 4800 baud.

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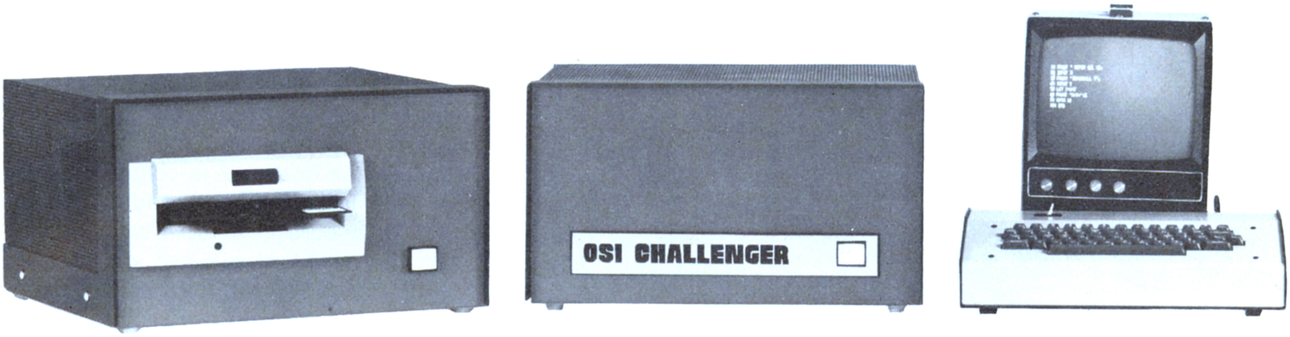

Imagine a system complete with terminal, CPU, memory, floppy disk, software, and all the little necessities to make it work together immediately. Now imagine this complete system available not only fully assembled, but priced much lower than anyone else's kit. What you are dreaming of is OSI's "new" Challenger System!

In the configuration shown above, the Challenger includes everything an end user needs for a complete small computer system. All you add is 110 VAC power and a desk to put it on. This fully-assembled system includes:

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APPLICATIONS:

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PRICES:

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As above without terminal. Specify RS-232 or 20ma loop and baud rate

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IMPORTANT NOTE:

One of the most important features of the Challenger System is that it is not really "new". OSI has been delivering the basic circuitry of the Challenger since November 1975 and the floppy disk since June 1976. The only thing new is the total integration of the components as a complete, simple to use, fully-assembled, small computer system.

For more free information and the address of the OSI Computer Dealer or representative in your area, write to: OSI; Dept. S; Hiram, Ohio 44234 or enclose $1.00 for the full OSI catalog which contains kits from $134 and fully assembled computers from $439.

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One-Sided View of Wire Wrap Sockets

Ira Rampil
Dept of Electrical and Computer Engineering
University of Wisconsin—Madison
Madison WI 53706

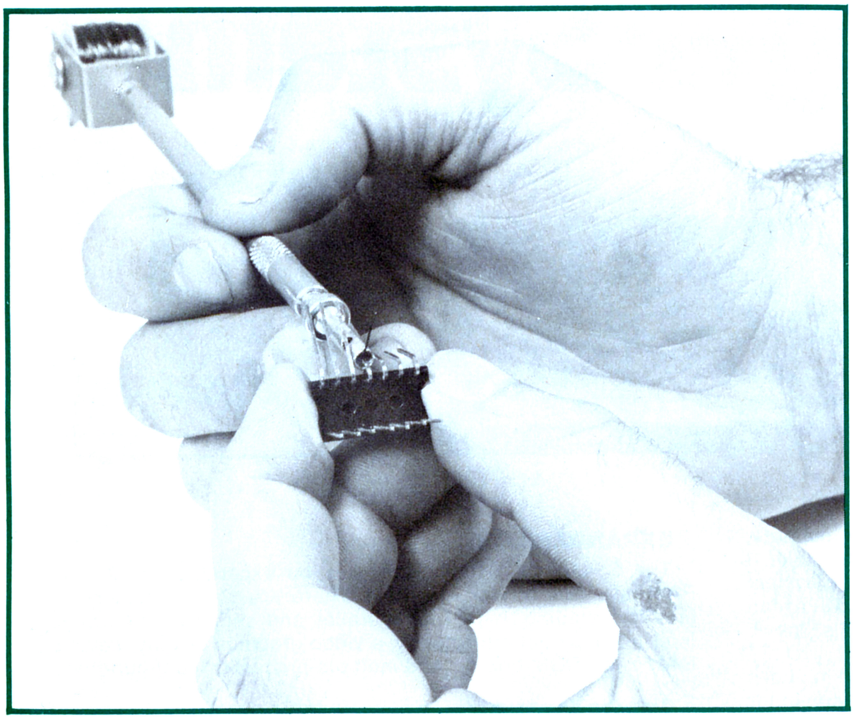

Photo 1: Bending a socket pin with a Slit-N-Wrap tool. The Slit-N-Wrap is positioned approximately 0.1 inch (0.254 cm) from the bottom of the socket, and the pin is bent up so it lines up vertically with the holes on the top of the socket. Three pins on this socket have already been bent showing what the result looks like.

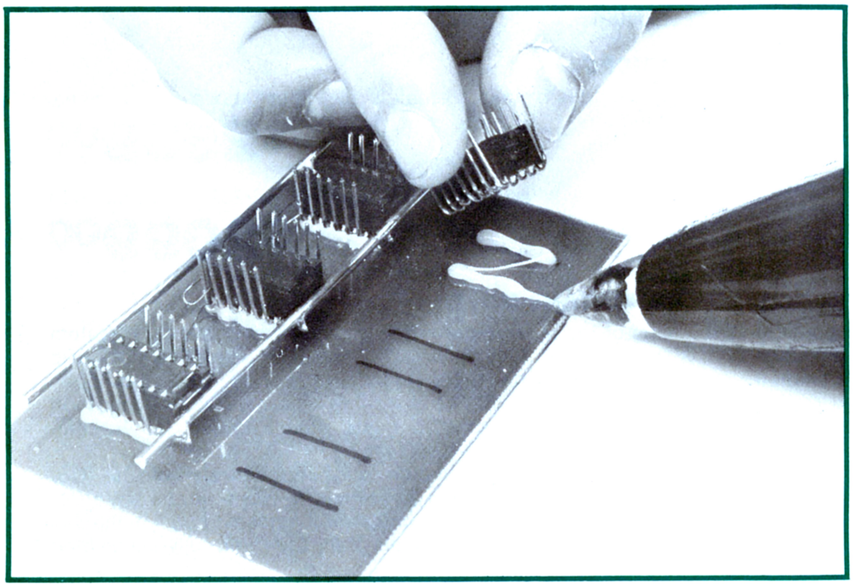

Photo 2: A mounting procedure for sockets. First determine where the sockets will be placed and make a mark where the pins contact the board (the black marks on the board). Using a hot glue gun, put a generous amount of glue on the board at the spot where the pins contact. Put the socket down on the glue and hold for a few seconds until the glue cools.

Recently, while laying out the components for a new PDP-11 device controller, a devilishly simple construction technique revealed itself to me. Digital Equipment Corporation specifies that their printed circuit modules be restricted to component heights of 0.38 inch (0.97 cm), and on the solder side only 0.06 inch (0.15 cm) are allowed for the height of soldered and clipped off leads. These specifications enable boards to be mounted on half inch centers on a backplane. A problem arises, however, if wire wrap or Vector Slit-N-Wrap is the desired interconnection technique. DEC's solution to this problem is to provide a circuit board with soldered sockets for the integrated circuits. Each socket pin is connected by a foil trace to a wire wrap post staked and soldered to the component side of the board. Aside from meeting the DEC dimensional specifications, there is another important benefit. Since the wire wrapping is now done on the same side as the components, it's harder to get lost and make erroneous connections. The only caveat is to route the wires so they do not cross directly over any chip, otherwise you will have difficulties replacing defective components.

There are two difficulties in using DEC manufactured boards in my, or any other, microprocessor application. The first problem is flexibility; the layouts are prearranged and there is no provision for 40 pin chips. The second problem is cost; a so called quad board which measures about 10.5 by 8.5 inches (26.7 by 21.6 cm) costs approximately $160.

The new technique which is described here retains all of the DEC board advantages with ultimate flexibility of layout, and very low cost. The best advantage is simplicity. The entire technique consists of bending the leads of a conventional wire wrap socket around so that they point upwards, and then gluing the socket down on a blank, unperforated board. The photos demonstrate the technique using a new Slit-N-Wrap pencil, by Vector Electronic Company.

For best result:

- Use quality sockets that have their posts solidly embedded in plastic, so they

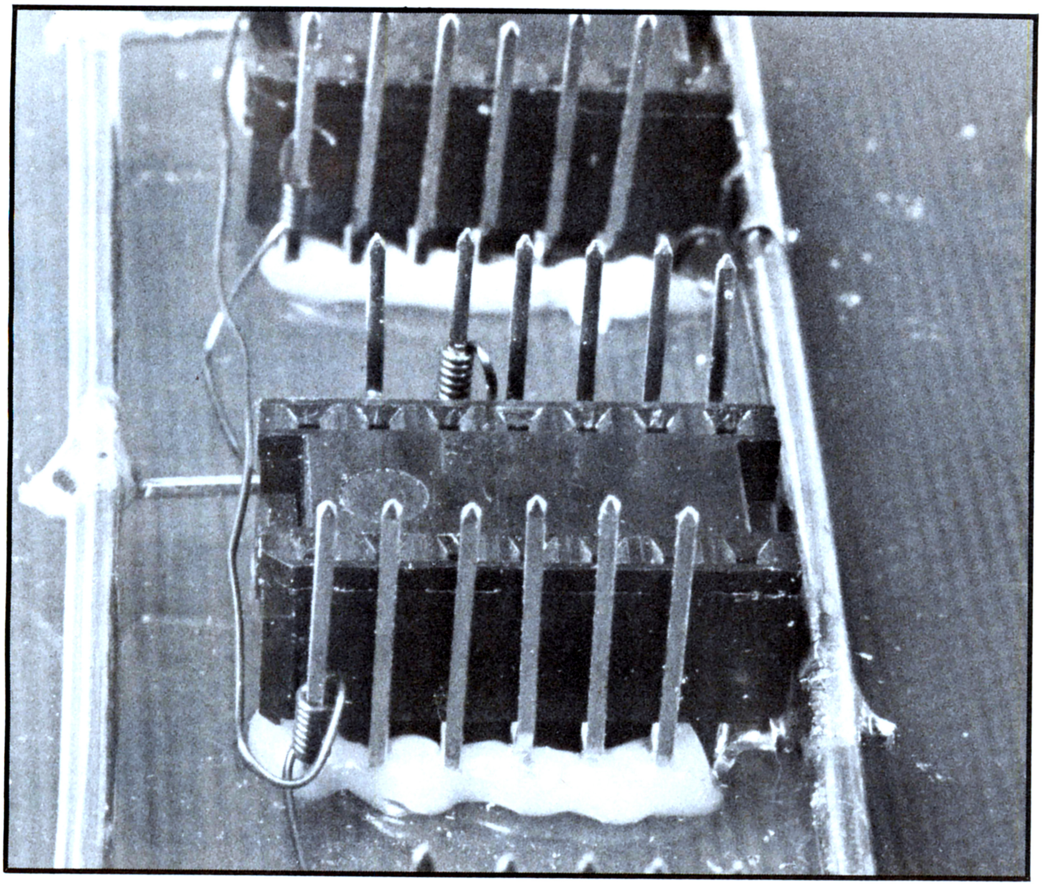

Photo 3: Closeup view of several mounted sockets. Notice how the glue is sitting at the bends in the pins, assuring a good mechanical connection and secure mounting. One very important item should be noticed: none of the wires cross other sockets. This is to prevent difficulties with changing circuits, should one fail. The heavy copper bars running on either side of the sockets are power connections. Notice that pins 7 and 14 are connected to these bars for ground and +5 V.

will not be pulled out during the bending operation.

- Use a metal wire wrap pencil to do the bending. It is exactly the right size for the job. Slide the pencil down each post to a point about 0.1 inch (0.254 cm) from the socket base. Slowly bend the post out straight, away from the socket, and then up along the body. Remove the pencil and press the bent post flat against the socket to remove some of the remaining angle. The bent posts should be vertically aligned with each respective pin contact in the socket. Use of the wire wrap pencil leaves just enough room between the post and the socket for the wrapping operation.
- One method of gluing the sockets down is to mix a small solution of epoxy glue and briefly press each socket into the glue so that all of the bends in the posts receive a small dab of glue. After all of the sockets are in place, bake the board in an oven at approximately 140°F for an hour or until the glue hardens. A faster method is to use a hot glue gun as shown in photo 2. It will prove useful to roughen a smooth circuit board with a file or sandpaper prior to gluing to achieve a stronger board. If mechanical shocks are anticipated this is an essential consideration.
- Route all of the wires into the spaces between sockets. Never cross a socket. This will allow you to easily replace the individual integrated circuits.
- The Slit-N-Wrap tool is a very easy and inexpensive way to wire wrap. It is convenient for doing daisy chaining with. My only complaint with the system is the means of cutting the wire. I think a surgeon's iris scissor or other small cutting tool would be much better than the tiny chisel provided by Vector. ■

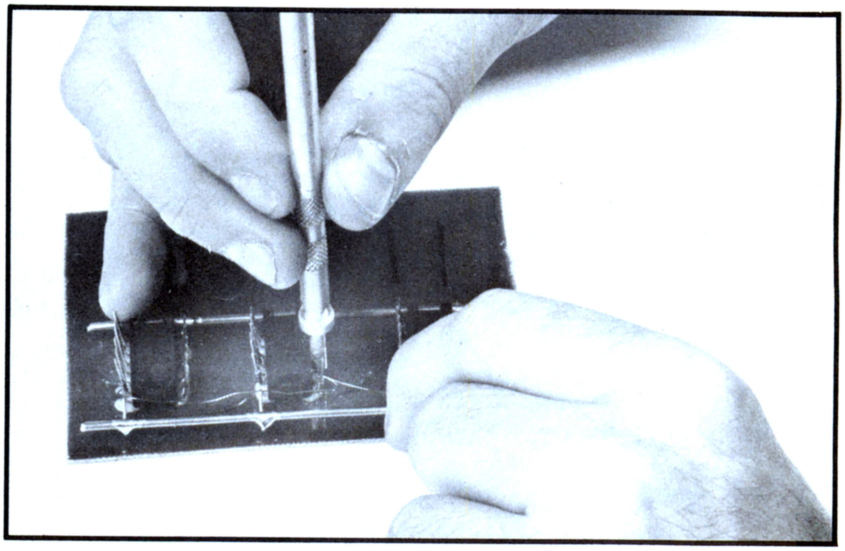

Photo 4: View of the Slit-N-Wrap in action on the one-sided prototyping board. Notice how the tip of the tool fits snugly on the pin with very little room between it and the socket.

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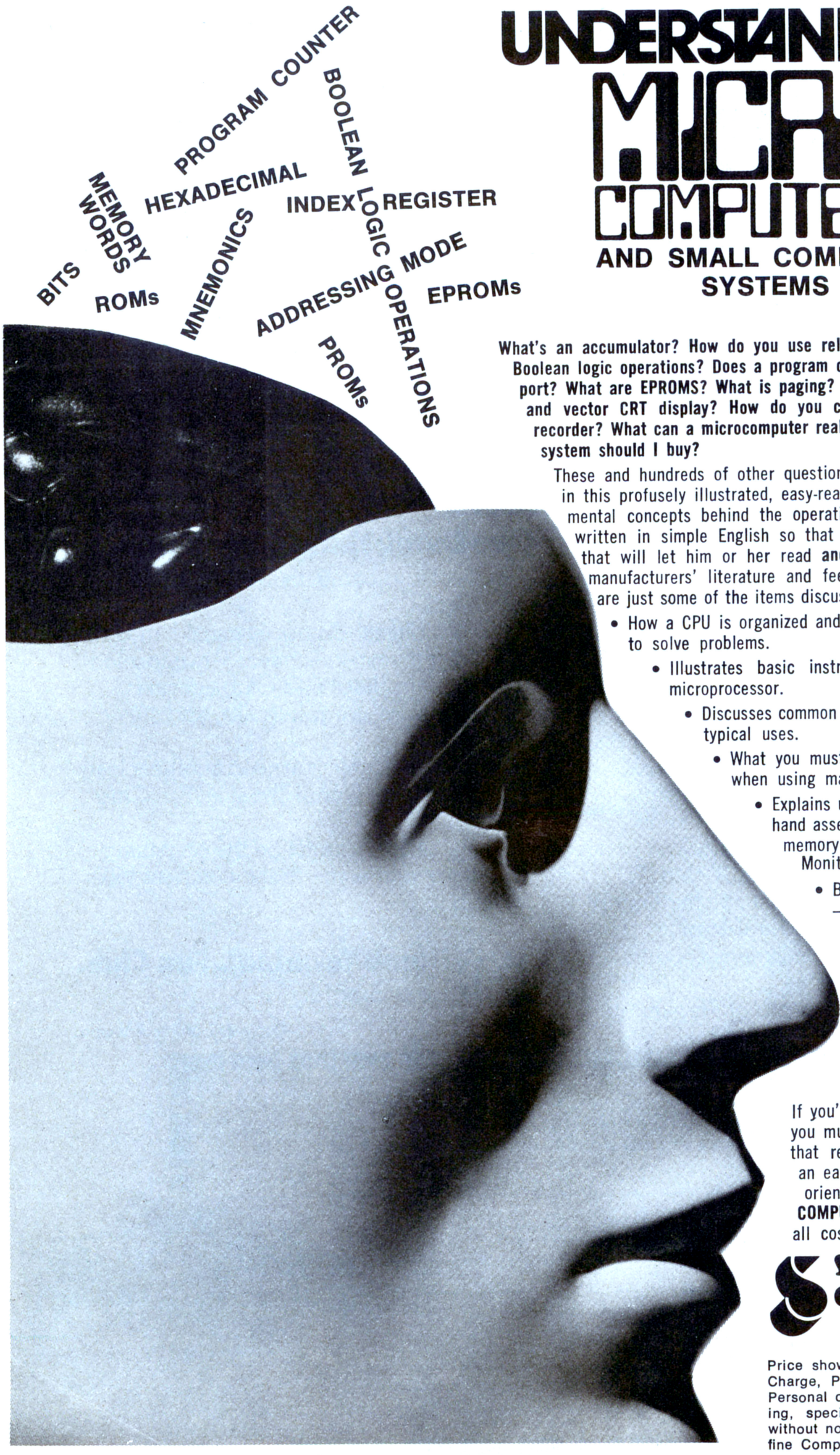

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Personal Computer Network

The PCNET (Personal Computer NETwork) Committee has been functioning in the Palo Alto area since the April 1977 West Coast Computer Faire. The committee's goal is the creation of regional (followed by national) personal computer networks for the computer to computer transfer of messages and files. A set of network protocols (sets of conventions defining all levels of intercomputer communication) is almost completely designed. These protocols should be operable in 8 K bytes of machine copy, and are designed to be implemented in string BASIC.

The committee believes this should be attractive to personal computer users. Participation will be voluntary; you can decide to participate (or not) on any given day of network operation. Network functioning will be relatively insensitive to the absence of an appreciable fraction of member computers.

Our current thinking indicates the following tentative equipment required for participation in the network:

- A personal computer with 12 to 16 K of user memory and string BASIC.
- An originate/answer MODEM capable of 300 bps.

A message service: the ability to send a message (generally English text, although almost any file can be sent) is quite valuable. It doesn't sound very dramatic, but it is surprising how powerful and efficiency improving such a message exchange facility is. What keeps ordinary message services (telephone, telegraph, mail) from working well seems to be a combination of factors: too slow (mail); often hard to catch someone (phone); difficult or time consuming to use (mail, telegrams); expensive in terms

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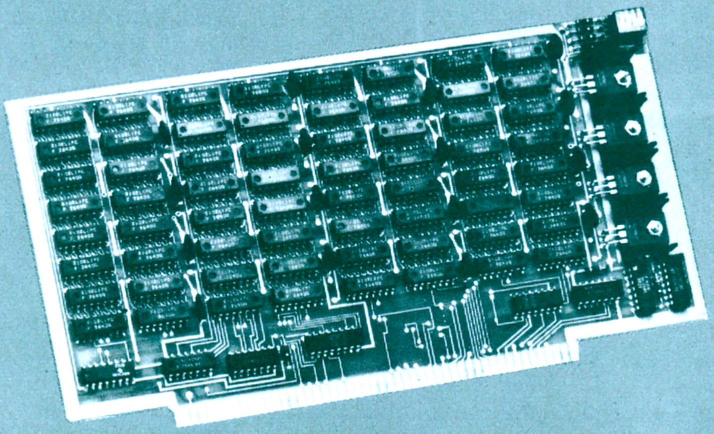

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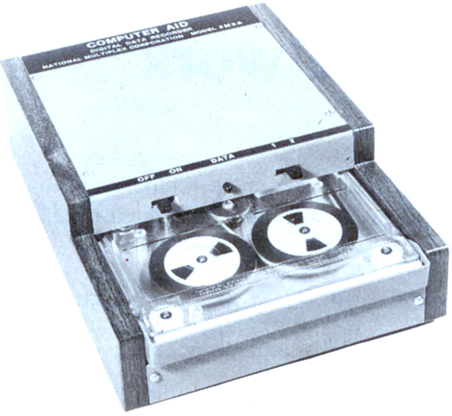

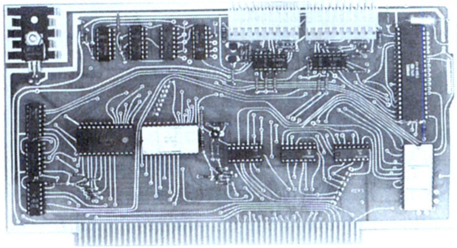

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Tape speed is 3.2"/second nominal; 1.6"/sec. optional. 110 volt, 60 Hz, 5 watts. (220 Volts on special order). Can use high quality audio cassettes (Philips Type) or certified data cassettes. Can be used in remote locations from a 12 Volt battery.

Recommended for DATA LOGGING, WORD PROCESSING, COMPUTER PROGRAM RELOADING and DATA STORAGE. Especially recommended for 6800 systems, 6502 systems, 1800 systems and beginners with the 8080 systems. Manual control except for motor start/stop. 6800 or 8080 software for file or record searching available on request with order. Used by major computer manufacturers, Bell Telephone and U.S. Government for program reloading and field servicing. AVAILABILITY – Off the shelf.

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Tape speed 10"/sec. on record, up to 30"/sec. on playback. Records one clock track and one data track on each pass (2 passes). Recording is NRZ unencoded from RS232 or TTL signals.

This recorder requires one Parallel port for motor control, and one serial port for data and clock. (Cannot be used with UART's or UART boards such as the 3P+S). Used with USART's, ACIA's or other 1/1 clocking I/O devices under software control only. No manual controls. Software for 8080 and 6800 available. Power supply is built in, 110V, 60 Hz. 220 V, 50 Hz for export.

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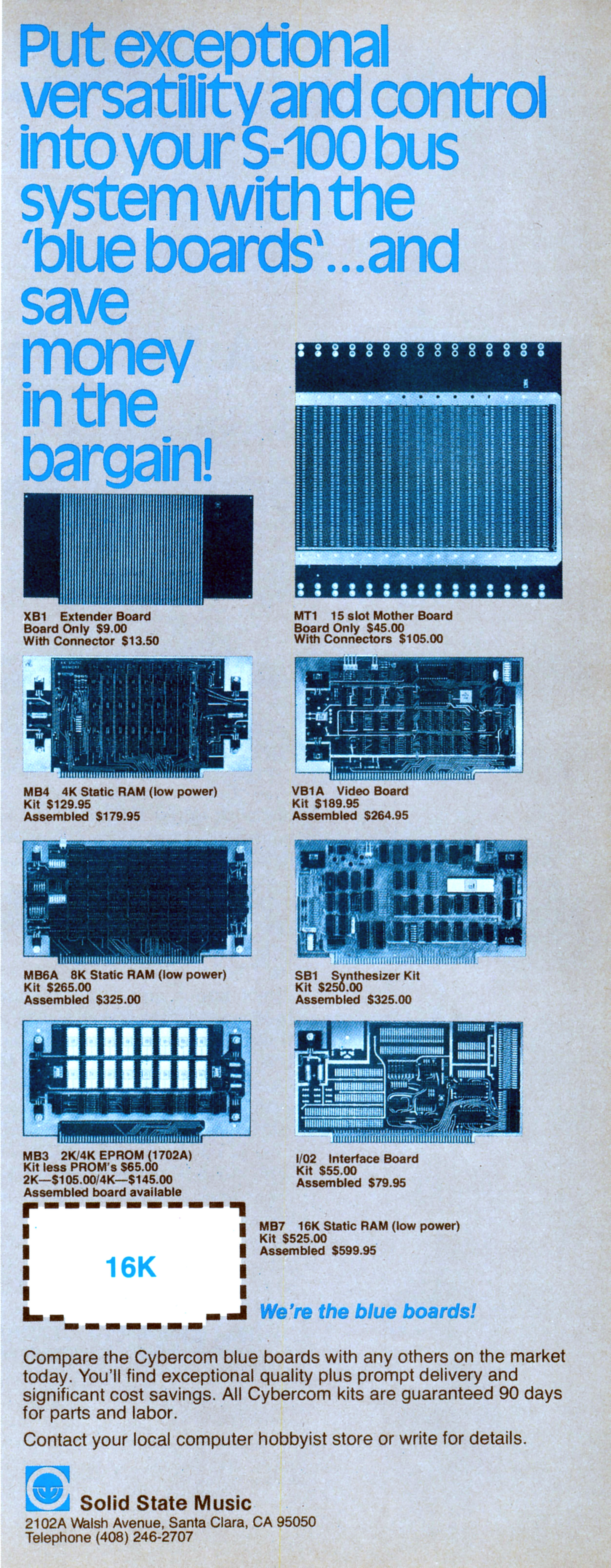
Continued on page 184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A Sampling of Techniques for Computer Performance of Music

Hal Chamberlin
29 Mead St
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Computer music is probably one of the most talked about serious applications for home computers. By serious I mean an application that has a degree of complexity and open-endedness which can totally preoccupy experimenters and funded institutions for years. Computer performance of music is a discipline so vast that the final, "best" technique for its implementation or even a good definition of such a technique may never be discovered.

At the same time, computer music is an easy field to break into. With only minimal effort and expenditure a very impressive (to the uninitiated) music performance demonstration may be put together. With a little more work a system may be assembled which is of great value to other family members, particularly children just starting to learn music theory. Such a system could, for example, eliminate manual dexterity as a factor in a child's musical development. Finally, on the highest level, it is no longer very difficult to break into truly original research in serious performance of music by computer. The advances in digital and linear integrated circuits have made putting together the hardware system for supporting such research largely a matter of clever system design rather than brute financial strength. Programming, tempered with musical knowledge, is the real key to obtaining significant results. Thus, in the future, hobbyists working with their own systems will be making important contributions toward advancement of the computer music art.

While the scope of one article cannot fully cover such an extensive topic, it should serve to acquaint the reader with the more popular techniques, their implementation, strengths, weaknesses, and ultimate potential.

Generally, all computer music performance techniques can be classified into two generic groups. The first includes schemes in which the computer generates the sound directly. The second covers systems where the computer acts as a controller for external sound generation apparatus such as an electronic organ or sound synthesizer.

Early Techniques

Just as soon as standard commercial computers such as the IBM 709 and, later, the 1401 made their appearance, programmers started to do frivolous things with them after hours, such as playing games and music. Since elementary monotonic (one note at a time) music is just a series of tones with different frequencies and durations, and since a computer can be a very precise timing device, it did not take long for these early tinkerers to figure out how to get the machine to play such music. The fundamental concept used was that of a *timed loop*.

A timed loop is a series of machine language instructions which are carefully chosen for their execution time as well as function, and which are organized into a loop. Some of the instructions implement a counter that controls the number of passes through the loop before exiting.

Let's examine some fundamental

timed loop relationships. If the sum total execution time of the instructions in the loop is M microseconds then we have a loop *frequency* of

$$\left(\frac{10^6}{M}\right) \text{ Hertz (cycles per second).}$$

If the initial value of the decrementing counter that controls the number of loop passes is N, then the total execution time before exit from the loop is (MxN) microseconds. Thus what we really have is a "tone" with a *frequency* of

$$\left(\frac{10^6}{M}\right)\text{Hertz}$$

and a *duration* of

$$\frac{M \times N}{10^6} \text{ seconds.}$$

Using different loops with more or fewer instructions will give us different Ms and thus different notes. Using different Ns when entering these loops gives different durations for the notes, and so we have satisfied the definition of elementary monotonic music.

Of course at this point the computer is merely humming to itself. Several techniques, some of them quite strange, have evolved to make the humming audible to mortals.

One such method that doesn't even require a connection to the computer is to use an AM portable radio tuned to a quiet spot on the broadcast band and held close to the computer. Viola! */Sic/* The humming rings forth in loud, relatively clear notes. As a matter of fact, music programs using this form of output were very popular in the "early days" when most small system computers had only 256 bytes of memory and no IO peripherals except the front panel.

What is actually happening is that the internal logic circuitry with its fast rise time pulses is spewing harmonics that extend up into the broadcast band region of the radio spectrum. Since some logic gates will undoubtedly switch only once per loop iteration, the harmonics of the switching will be separated in frequency by the switching or loop frequency. Those high frequency harmonics that fall within the passband of the radio are treated as a "carrier" and a bunch of equally spaced nearly equal amplitude sidebands. The radio's detector generates an output frequency equal to the common differences of all these sidebands, which is the loop frequency and its harmonics. The timbre of the resulting tones is altered somewhat by the choice of instructions in the loop, but basically has a flat audio spectrum like that of a narrow pulse waveform. Noise and distortion arise from other logic circuitry in the computer which switches erratically with respect to the timed loops. One practical difficulty with this method is there is no clearly identifiable way to get the computer to "shut up" for rests or space between identical notes.

The Hammer-Klavier

Other early methods used some kind of output peripheral to make sound. In a demonstration of an IBM 1401 over a decade ago this was literally true: the computer played a line printer! It seems that the hookup between a 1401 central processing unit and the 1403 printer was such that software had control of the printer hammer timing. Each time a hammer was fired a pulse of sound was emitted upon impact with the paper. Using a timed loop program with a print hammer fire instruction imbedded in the loop gave a raspy but accurately pitched buzz. */It also tended to cause IBM customer engineers great trepidation . . .*CH/ This same scheme should also be possible on some of the small, completely software controlled dot matrix printers that are now coming on the market.

A sane approach, however, is to connect a speaker to an output port bit through an amplifier. Instructions would then be placed inside the timed loops to toggle the bit and thus produce a clean, noise-free rectangular wave.

Timed Loop Example

Let's look at an example of a timed loop music playing program, not so much for its musical value (which is negligable), but for some insight into what is involved, and also to introduce some terms. The MOS Technology 6502 microprocessor will be used for these examples. These programs are designed to run on a KIM-1 system, and should run on most other 6502-based systems with very minor modifications. Motorola 6800 users should be able to easily convert the programs into 6800 machine language. 8080 users will benefit most because successful conversion indicates a thorough understanding of the concepts involved.

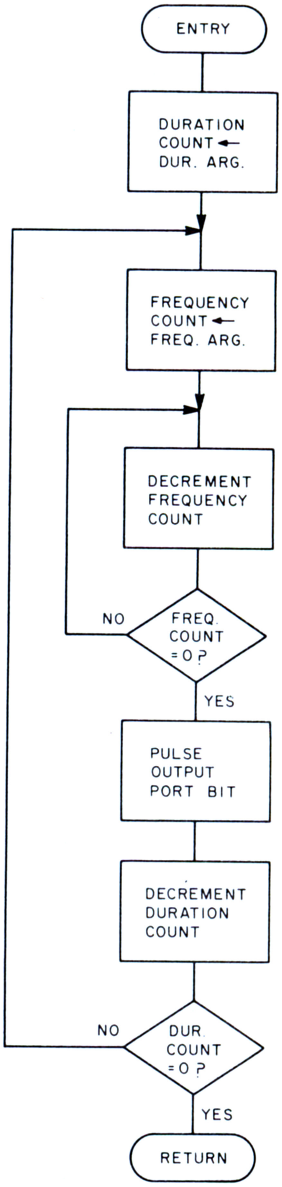

Figure 1: A basic tone generation subroutine. There are two nested loops in this routine: the first, or inner loop controls the frequency (or pitch) of the note to be generated, while the second, outer loop controls the duration of the note. A train of square waves is generated at the output port bit which is used to drive the circuit in figure 2 to produce an audible tone.

Note	**Frequency (Hz)**
Middle C	261.62
C#	277.18
D	293.66
D#	311.13
E	329.63
F	349.23
F#	369.99
G	391.99
G#	415.30
A	440.00
A#	466.16
B	493.88

Table 1: Equally tempered scale note frequencies in Hertz. In order to determine frequencies of notes in the higher octaves, multiply by 2 for each octave above this one. For lower octaves, divide by 2 for each lower octave.

The heart of the program is the tone generation subroutine which will be named TONE. Ideally, such a routine would accept as input two arguments: one related to the pitch of the note and the other controlling the duration. With such a subroutine available, playing a piece of music amounts to simply fetching the arguments from a "song" table in memory and calling the routine for each note to be played.

As mentioned previously, we could have a separate, carefully timed loop for each different tone frequency needed. TONE would then call the proper one based on the pitch parameter. Indeed this approach is very accurate (to within 1 μs on the 6502) but a great deal of memory is consumed for the 30 or so notes typically required. It also lacks flexibility. (This will be discussed later.) A better approach is to embed a second, *waiting* loop to control the execution time of one pass through the outer loop, and thus the tone's frequency. Figure 1 is a flowchart illustrating this. When using this scheme, the frequency argument directly determines the number of times through the inner, waiting loop and the duration parameter directly determines the number of times through the outer, tone generation loop.

Now, how are the argument values determined to get the frequencies and durations desired? First the execution time of the nested loops must be determined. In the KIM-1 with a 1 MHz clock and a 6502 the tightest inner waiting loop that can be written is 5 μs, assuming that the inner loop count (frequency argument) is 256 or less and that it is held in a register. The total time spent in the loop is [(5xM)-1]) microseconds, where M is the frequency argument and the -1 is due to the shorter execution time of an unsuccessful branch. (The observant reader will note that the execution time of some 6502 instructions is altered if they cross a memory "page boundary"; thus, an assumption of no page crossing is made.) But there is still the time required for a pass through the outer loop to output a pulse and decrement the duration counter. This is termed "loop overhead." For an example, let's say that the loop overhead is 25 μs. As a result, the total outer loop time is [(5xM)-1+25], or [(5xM)+24] microseconds which is the period of the audio waveform output. In order to determine the M required for a particular note, a table of note frequencies (see table 1) is consulted. Then the equation,

$$M = \frac{\left(\frac{10^6}{F} - 24\right)}{5}$$

where F is the desired frequency, is solved for the nearest integer value of M. Lower frequency notes are preferred so that the percentage error incurred due to rounding M is minimized. The duration argument is actually a count of the number of audio tone cycles which are to be generated for the note, and thus its value is dependent on the note, and thus its value is dependent on the tone frequency as well as the duration. Its value can be determined from the relation N=DxF, where N is the duration argument, D is the duration in seconds, and F is the note frequency in Hertz.

As a complete example, let's assume that an eighth note G# an octave above middle C is to be played, and that the piece is in 4/4 time with a metronome marking of 80 beats per minute. Since an eighth note in this case is one half of a beat, the duration will be

$$\frac{0.5 \times 60}{80}$$

or 0.375 seconds. The note table shows that the frequency of G# an octave above middle C is 830.6 Hz, which yields a frequency argument of 236. The duration argument is 311. So if TONE is called with these parameters, a nice G# eighth note will be produced.

Now let's go a step further and look at a practical "music peripheral" and TONE subroutine. Figure 2 shows a circuit for driving a speaker from any kind of TTL compatible

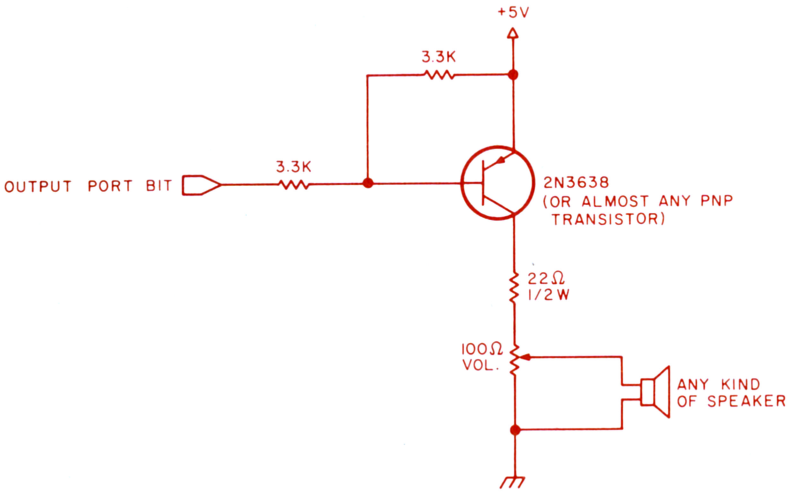

Figure 2: A speaker driver circuit designed to accept square or rectangular waves and produce audible tones through a loudspeaker. In this particular application the circuit is driven from an output port bit of a KIM-1 microcomputer, although the circuit can accept any TTL compatible output port bit. When the input to the circuit is a logical 0 level, the transistor turns on and drives the speaker. When the input is a logical 1, the transistor turns off and current to the speaker is interrupted.

Wave Duty Cycle	Harmonics Fund	2	3	4	5	6	7	8	9	10
1/2	1.00	0	0.333	0	0.200	0	0.143	0	0.111	0
1/3	1.00	0.500	0	0.250	0.200	0	0.143	0.125	0	0.100
1/4	1.00	0.707	0.333	0	0.162	0.236	0.143	0	0.111	0.141
1/5	1.00	0.841	0.561	0.259	0	0.173	0.240	0.210	0.116	0
1/6	1.00	0.867	0.667	0.433	0.200	0	0.143	0.217	0.222	0.173

Table 2: Harmonic amplitudes of rectangular waves. Note that, unlike square waves, asymmetrical rectangular waves contain even numbered harmonics. This simple technique of varying the duty cycle of such waves can have an appreciable effect on the timbre of the resulting sound.

output port bit, including those found in the 6530 "combo chips" used in the KIM-1. When the output port bit is a logic 0 level, the transistor turns on and drives a current determined by the volume control setting through the speaker. When the bit is a logic 1, the current is interrupted. Larger speakers or even a high fidelity speaker system will give a richer timbre to the lower pitched tones. The AUX input to a sound system may also be used instead of the transistor circuit. Using a patch cord, connect the shield to the common terminal of the power supply and the center conductor to the output port bit through a 10 K to 100 K isolation resistor.

Listing 1 shows an assembled listing of a practical timed loop tone generation subroutine for the 6502 microprocessor. Several refinements beyond the flowcharted example have been made to improve tone quality and flexibility. The inner waiting loop has been split into two loops. The first loop determines the length of time that the output rectangular waveform is to be a logic 1 and the second loop determines the 0 time. If both loops receive the same frequency argument (which they do as written) and the loop time of both loops is the same, then a symmetrical square wave output is produced. However, if one or more "do nothing" instructions is inserted into one of the two loops, the output waveform will become nonsymmetrical. The significance of this is that the rectangular waveform's duty cycle affects its harmonic spectrum, and thus its timbre. In particular, there is a large audible difference between a 50%-50% duty cycle (square wave) and a 25%-75% duty cycle. Table 2 lists the harmonic structure of some possible rectangular waves. As a result, some control over the timbre can be exercised if a separate TONE subroutine is written for each "voice" desired. Unfortunately, if this is done the frequency arguments will have to be recomputed since the outer loop time will then be altered.

Real music also possesses *dynamics,* which are the changes in overall volume during a performance. Furthermore, the *amplitude envelope* of a tone is an important contributor to its overall subjective timbre. The latter term refers to rapid changes in volume during a single note. This is the case with a piano note, which builds up rapidly at the beginning and slowly trails off thereafter. Of course the setup described thus far has no control over either of these parameters: the volume level is constant, and the envelope of each note is rectangular with sudden onset and termination.

```
                  ;         TONE SUBROUTINE FOR 6502
                  ;         ENTER WITH FREQUENCY PARAMETER IN ACCUMULATOR
                  ;         DURATION PARAMETER STORED AT LOCATION DUR (LOW PART) AND
                  ;         DUR+1 (HIGH PART) WHICH IS ASSUMED TO BE IN PAGE ZERO
                  ;         ROUTINE USES A, X, AND DESTROYS DUR
                  ;         LOOP TIME = 10*(FREQ PARAMETER)+44 MICROSECONDS

1700              MPORT     =      X'1700        ; ADDRESS OF OUTPUT PORT WITH SPEAKER
00E0              DUR       =      X'E0          ; ARBITRARY PAGE 0 ADDRESS OF DURATION PARM

0100 A2FF         TONE:     LDX    #X'FF         ; SEND ALL 1'S TO THE OUTPUT PORT
0102 8E0017                 STX    MPORT
0105 AA                     TAX                  ; TRANSFER FREQ PARAMETER TO INDEX X
0106 CA           WHIGH:    DEX                  ; WAIT LOOP FOR WAVEFORM HIGH TIME
0107 D0FD                   BNE    WHIGH         ; TIME IN THIS LOOP = 5*FREQ PARAMETER
0109 F000                   BEQ    .+2           ; WAIT 15 STATES TO MATCH TIME USED TO
010B F000                   BEQ    .+2           ; DECREMENT AND CHECK DURATION COUNT AFTER
010D F000                   BEQ    .+2           ; WAVEFORM LOW TIME
010F F000                   BEQ    .+2
0111 F000                   BEQ    .+2
0113 A200                   LDX    #0            ; SEND ALL 0'S TO THE OUTPUT PORT
0115 8E0017                 STX    MPORT
0118 AA                     TAX                  ; TRANSFER FREQ PARAMETER TO INDEX X
0119 CA           WLOW:     DEX                  ; WAIT LOOP FOR WAVEFORM LOW TIME
011A D0FD                   BNE    WLOW          ; TIME IN THIS LOOP = 5*FREQ PARAMETER
011C C6E0                   DEC    DUR           ; DECREMENT LOW PART OF DURATION COUNT
011E D005                   BNE    TIMWAS        ; BRANCH IF NOT RUN OUT
0120 C6E1                   DEC    DUR+1         ; DECREMENT HIGH PART OF DURATION COUNT
0122 D0DC                   BNE    TONE          ; GO DO ANOTHER CYCLE OF THE TONE IF NOT 0
0124 60                     RTS                  ; RETURN WHEN DURATION COUNT RUNS OUT
0125 F000         TIMWAS:   BEQ    .+2           ; WASTE 7 CYCLES TO EQUAL TIME THAT WOULD
0127 F000                   BEQ    .+2           ; HAVE BEEN SPENT IF HIGH PART OF DUR WAS
0129 D0D5                   BNE    TONE          ; DECREMENTED AND GO DO ANOTHER CYCLE
```

Listing 1: An assembled listing of a practical timed loop tone generation subroutine for the 6502 microprocessor. This routine is an elaboration of the flowchart shown in figure 1 which allows the user to generate nonsymmetrical rectangular waves. Experimenting with the wave's duty cycle affects the harmonic content of the resulting tone and creates many interesting aural effects.

By graduating to a more sophisticated music peripheral, control of dynamics and amplitude envelopes can be achieved with a timed loop music program. The secret is to use a *digital to analog* converter connected to all eight bits of the output port. A digital to analog converter (DAC) does just what its name implies: it accepts a binary number from the output port as input and generates a corresponding DC voltage as its output.

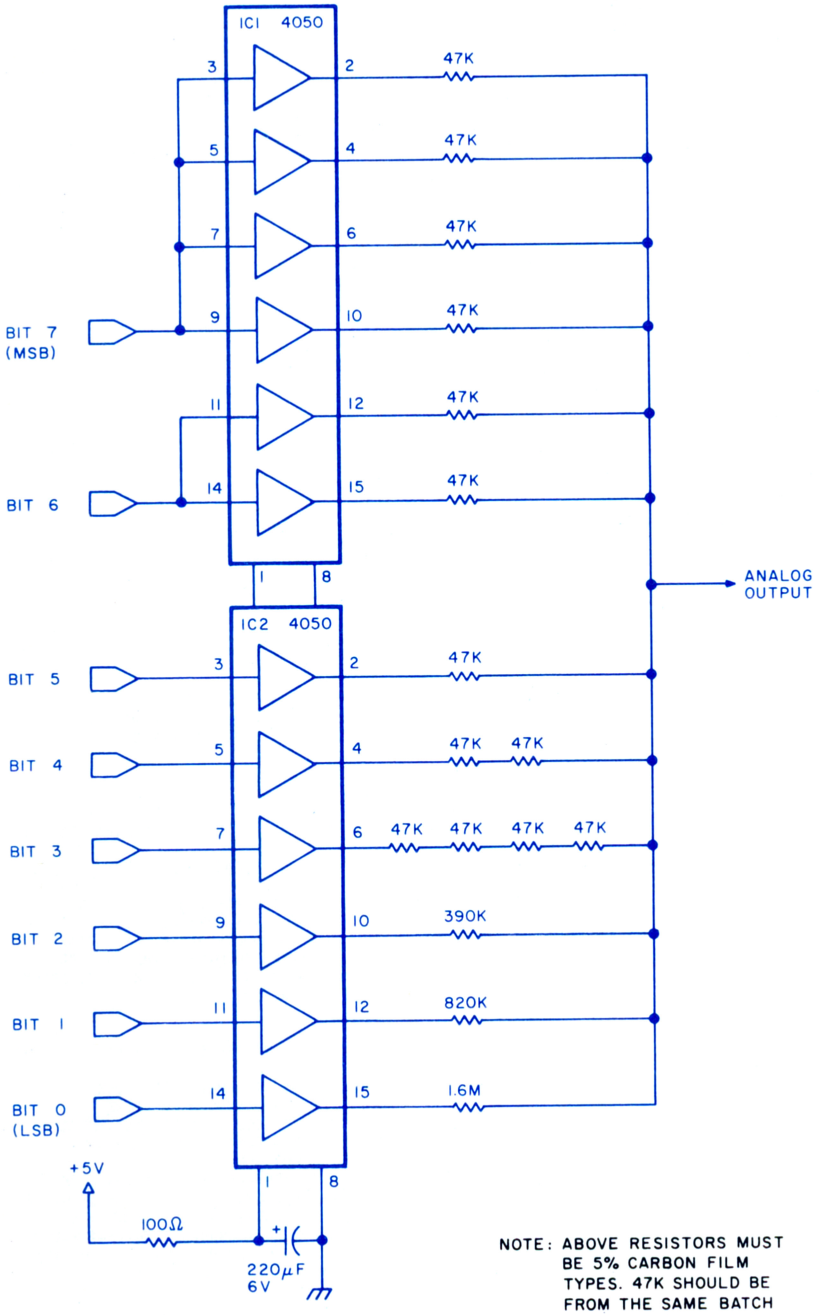

Figure 3: An 8 bit digital to analog converter (DAC). This circuit accepts an 8 bit binary number from the output port and generates a corresponding DC voltage as its output. The output voltage from this circuit is equal to ((I/255)-x5) V, where I is the decimal equivalent of the 8 bit input which can take on any value from 0 to 225.

The circuit in figure 3, which can be used with any TTL compatible output port, gives an output voltage

$$V=\left(\frac{I}{255}\right)x5$$

where I is the binary number input between 0 and 255. When working with this kind of DAC, it is convenient to regard the binary number, I, as a fraction between 0 and 1 rather than an integer. The benefit of this will become apparent later when calculations will be performed to arrive at the value of I. The output of the DAC must be used with a sound system or the amplifier circuit in figure 8, not the simple transistor speaker driver circuit in figure 2.

As written, the TONE subroutine (see listing 1) alternately sends 0 and 255 to the output port with the music peripheral. With a DAC connected to that port, voltages of 0 and 5 V will be produced for the low and high portions of the rectangular wave. If instead 0 and 127 were output, the DAC would produce only 0 and 2.5 V giving a rectangular wave with about half the amplitude. This in turn produces a less loud tone, and so control over dynamics is possible by altering the byte stored at hexadecimal 101.

Arbitrary amplitude envelopes are also made possible by continuously exercising control over the amplitude during a note. Simple envelope shapes such as a linear attack and decay can be computed in line while the note is being sounded. A more general method is to build a table in memory describing the shape. Such a table can be quickly referenced during note playing. Great care must be taken, however, to insure that loop timing is kept stable when the additional instructions necessary to implement amplitude envelopes are added.

More Complex Techniques

Even if all of the improvements mentioned above were fully implemented, the elementary timed loop approach falls far short of significant musical potential. The primary limitations are a narrow range of tone colors and restriction to monotonic performance. The latter difficulty may be alleviated through the use of a multitrack tape recorder to combine separate parts, but this requires an investment in noncomputer hardware and is certainly not automatic. Also, unpitched percussive sounds such as drum beats are generally not possible. Musicians, too, will probably notice a host of other limitations such as lack of vibrato and

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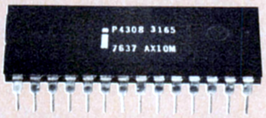

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```
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```

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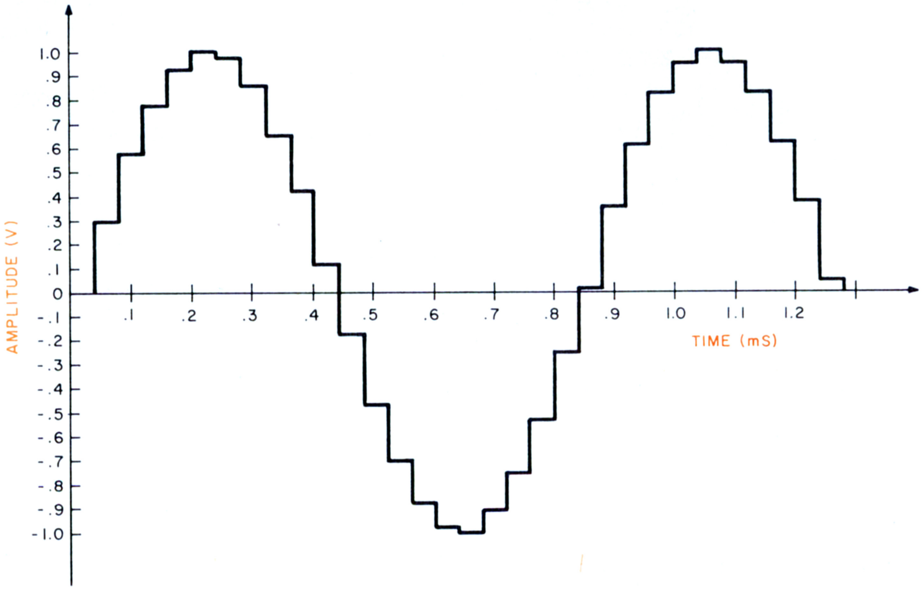

Figure 4: A sine wave as it would appear at the output from the digital to analog converter shown in figure 3. Each step in the approximation of this wave is called a sample. This particular illustration shows a 1.2 kHz sine wave sampled at a rate of 25,000 samples per second. The resulting waveform is only a very rough approximation of the original, but low pass filtering can improve accuracy (see figure 5 and text).

other subtle variations. All of these shortcomings may be overcome by allowing the computer to compute the entire sound waveform in detail at its own speed.

The one fundamental concept that makes direct waveform computation possible is the *sampling theorem*. Any waveform, no matter how simple or complex, can be reconstructed from a rapid series of discrete voltage values by means of a digital to analog converter such as the one used earlier. As an example, let's try to generate an accurate sine wave using a DAC. If this can be done, it follows from the Fourier (harmonic) theorem that any other waveform may also be synthesized.

Figure 4 shows a sine wave as it would appear at the DAC output. Each step on the approximation to the sine wave is termed a *sample*, and the frequency with which these samples emerge from the DAC is the *sample rate*. An attempt is being made in the example to generate a 1.2 kHz sine wave at a sample rate of 25 kHz, or one sample every 40 μs. Obviously this is a very poor sine wave, a fact that can be easily demonstrated with a distortion analyzer.

Before giving up, let's look at the frequency spectrum of this staircase-like wave on a spectrum analyzer. The spectral plot in figure 5 shows a strong frequency component at 1.2 kHz which is the sine wave we are trying to synthesize. Also present are the distortion component frequencies due to the sampling process. Since all of the distortion components are much higher in frequency than the desired signal, they may be easily removed with a sharp low pass filter. After filtering, the distortion analyzer will confirm that a smooth, pure sine wave is all that remains.

What will happen if the sine wave frequency is increased but the sampling frequency remains constant? With even fewer samples on each sine wave cycle the waveform from the DAC will appear even more distorted. The lowest frequency distortion product is the one of concern since it is the most difficult to filter out. Its frequency is FD=(FS-f) Hertz, where FD is the lowest distortion component frequency, FS is the sampling frequency, and f is the sine wave signal frequency. Thus as f increases, FD decreases until they merge at f=FS/2. This frequency is termed the *Nyquist frequency* and is the highest theoretical frequency that may be synthesized. Any attempt to synthesize a higher frequency will result in the desired signal being filtered out and the distortion frequency emerging instead. This situation is termed *aliasing* because the desired signal frequency has been replaced by a distortion component alias frequency. Operating close to the Nyquist frequency requires a very sharp filter to separate the signal from the distortion. With practical filters, signal frequencies up to 1/4 to 1/3 of the sampling frequency are realizable.

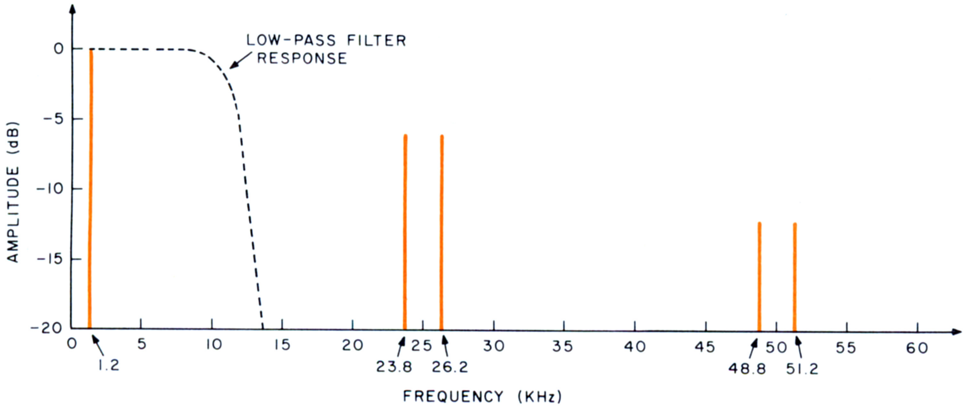

Figure 5: The spectral plot of the staircase-like sine wave approximation shown in figure 4. This frequency versus amplitude graph indicates a strong frequency component at 1.2 kHz, the frequency of the sine wave. Normally, this would be the only frequency component to appear on a plot like this, but the presence of steeply rising steps in this waveform approximation introduces distortion components at higher frequencies, as shown.

Since any sound, whether it is a pitched tone or unpitched sound, is actually a combination of sine waves, it follows that any possible sound may be produced by a DAC. The only limitation is the upper frequency response, which may be made as high as desired by increasing the sample rate. The low frequency response has no limit, and extends down to DC.

There is another form of distortion in DAC generated sounds which cannot be filtered out, since it is spread throughout the frequency spectrum. *Quantization noise* is due to the fact that a DAC cannot generate voltages that are exact samples on the desired waveform. An 8 bit converter, for example, has only 256 possible output voltage values. When a particular voltage is needed, the nearest available value will have to be used. The theoretical signal to noise ratio when using a perfect DAC is related to the number of bits by the equation S/N=(6xM)+4 decibels where M is the number of bits. A practical DAC may be as much as 6 db worse, but a cheap 8 bit unit can yield nearly 50 db, which is as good as many tape recorders. When using 12 bits or more, the DAC will outperform even the best professional recorders. Thus it is apparent that computed waveforms can, in theory, be used to generate very high quality music; so high, in fact, that conventional audio equipment is hard pressed to reproduce it.

Now that we have the tools, let's see how the limitations of computer music mentioned earlier can be overcome. For tones of definite pitch, the timbre is determined by the waveshape and the amplitude envelope. Concentrating on the waveshape, it should be apparent that a waveform table in memory repeatedly dumped into the DAC will produce an equivalent sound waveform. Each table entry becomes a sample, and the entire table represents one cycle of the waveform. The frequency of the resulting tone will be FS/N where FS is the sampling frequency (rate at which table entries are sent to the DAC) and N is the number of entries in the table. To get other frequencies, either the sample rate or the number of table entries must be changed.

There are a number of reasons why the sample rate should remain constant, so the answer is to change the effective table length. If the table dump routine were modified to skip every other entry, the result would be an effective halving of table size and thus doubling of the tone frequency. If the table is fairly long, such as 256 entries, a number of frequencies are possible by skipping an integer number of entries.

To get musically accurate frequencies, it is necessary to be able to skip a fractional number of table entries. At this point the concept of a *table increment* is helpful in dealing with programming such an operation. First, the table is visualized as a circle with the first entry conceptually following the last as in figure 6. A pointer locates a point along the circular table which represents the sample last sent to the DAC. To find what should be sent to the DAC next, the table pointer is moved clockwise a distance equal to the table increment. The frequency of the resulting tone is now

$$\frac{FSxI}{N}$$

where FS and N are as before and I is the increment.

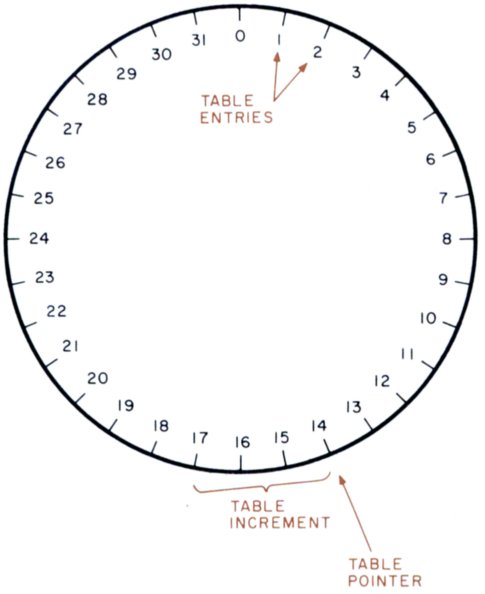

Figure 6: Diagrammatic representation of the circular table used for storing the waveform "template." The technique illustrated here is that of storing a large number of samples of one cycle of a musical waveform in memory as a table which wraps around itself in circular fashion. A pointer is used to point to the next sample to be extracted. In order to create a waveform with a given frequency, the program is designed to skip a fractional number of table entries to get the next sample value. This fractional number is called the table increment value. The process is continued around the table for one revolution to create a complete waveform. The cycle around the table is repeated until the duration counter decrements to zero.

With integer increments, the pointer always points squarely to an entry. With mixed number increments, the pointer also will take on a fractional part. The sensible thing to do is to interpolate between the table entries on either side of the pointer to arrive at an accurate value to give to the DAC. This is indeed necessary to assure high quality; but simply choosing the nearest entry may be acceptable in some cases, particularly if the table is very large.

There is one elusive pitfall in this technique. The table may contain the tabulation of any waveform desired, subject to one limitation: a nonzero harmonic component of the waveform must not exceed the Nyquist frequency, FS/2. This can easily happen with the larger table increments (higher frequency tones), the result being aliasing of the upper harmonics. Theoretically this is a severe limitation. Often a small amount of aliasing is not objectionable, but a large amount sounds like gross intermodulation distortion. High sample rates reduce the possibility or magnitude of aliasing, but of course require more computation. For the moment, we will ignore this problem and restrict ourselves to relatively smooth waveforms without a lot of high frequency harmonics.

Now that the DAC is used for generating the actual waveshape, how is amplitude control accomplished? If an amplitude parameter is defined that ranges between 0 and 1.0 (corresponding to amplitudes between zero and maximum), the desired result is obtained by simply multiplying each sample from the table by this amplitude parameter and sending the product to the DAC. Things are nice and consistent if the table entries are also considered as fractions between −1 and +1 because then the product has a range between −1 and +1 which is directly compatible with the DAC. (Note that the DAC in figure 3 is unipolar. It can be considered bipolar if +2.5 V output is the zero reference and the sign bit is inverted.)

The last major hurdle is the generation of simultaneous tones. Obviously, two simultaneous tones may be generated by going through two tables, outputting to two separate DACs, and mixing the results with an audio mixer. This is relatively simple to do if the sample rates of the two tones are the same. Actually, all the audio mixer does is to *add* the two input voltages together to produce its output, but a very important realization is that the addition can also be done in the computer before the output conversion by the DAC! The two samples are simply added together with an ADD instruction, the sum is divided by two (to constrain it to the range of −1 to +1), and the result sent to a single DAC. This holds true for any number of simultaneous tones! The only requirement is that the composite samples not overflow the −1 to +1 range that the DAC can accept. Rather than dividing the sum, it is best to adjust the amplitude factors of the individual "voices" to prevent overflow. So now we have the tools necesary to generate an ensemble of tones, each one possibly having its own waveform, amplitude envelope, and loudness relative to the others. Indeed, this is all that is necessary to simulate a typical organ.

Up to this point the timbre (waveform) of a tone has been determined by the contents of a fixed waveform table. Truly interesting musical notes change their timbre during the duration of the note. A reasonable alternative to switching between similar tables for implementing this is to build the tone from harmonic components. Each harmonic component of the tone is simply

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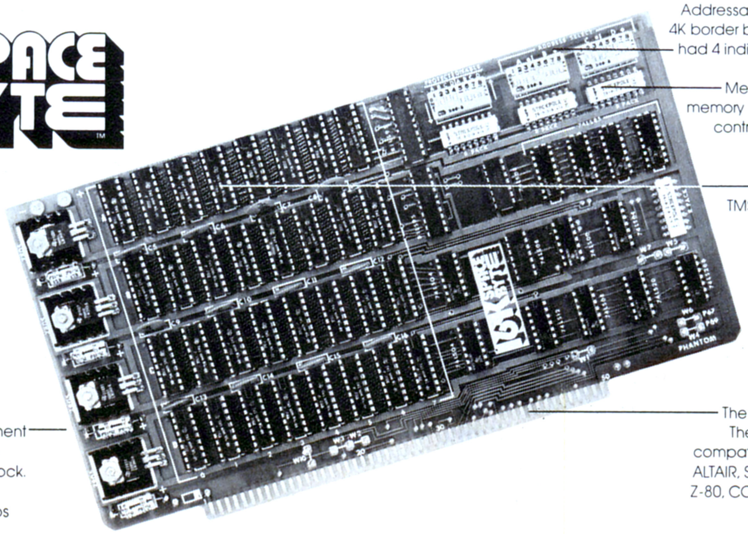

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Listing 2: A program which, in conjunction with tables 3, 4 and 5, generates four simultaneous musical voices, each with a different waveform and volume level. The program is designed for use with the 6502 processor coupled to an 8 bit unsigned digital to analog converter (DAC) like the one shown in figure 3.

```
                ;       THIS PROGRAM PLAYS MUSIC IN 4-PART HARMONY ON THE KIM-1 OR
                ;       OTHER 6502 BASED SYSTEM USING AN 8-BIT UNSIGNED
                ;       DIGITAL-TO-ANALOG CONVERTER CONNECTED TO AN OUTPUT PORT.  TUNED
                ;       FOR SYSTEMS WITH A 1 MHZ CRYSTAL CLOCK.  DOES NOT USE THE ROR
                ;       INSTRUCTION.
                ;       SONG TABLE IS AT "SONG"
                ;       ENTRY POINT IS AT "MUSIC"

0000                    .=      0               ; ORG AT PAGE 0 LOCATION 0

1700            DAC     =       X'1700          ; OUTPUT PORT ADDRESS WITH DAC
1701            DACDIR  =       X'1701          ; DATA DRIECTION REGISTER FOR DAC PORT
1780            AUXRAM  =       X'1780          ; ADDRESS OF EXTRA 128 BYTES OF RAM IN 6530
1C22            KIMMON  =       X'1C22          ; ENTRY POINT TO KIM KEYBOARD MONITOR

0000 00         V1PT:   .BYTE   0               ; VOICE 1 WAVE POINTER, FRACTIONAL PART
0001 0000               .WORD   WAV1TB          ; INTEGER PART AND WAVE TABLE BASE
0003 00         V2PT:   .BYTE   0               ; VOICE 2
0004 0000               .WORD   WAV2TB
0006 00         V3PT:   .BYTE   0               ; VOICE 3
0007 0000               .WORD   WAV3TB
0009 00         V4PT:   .BYTE   0               ; VOICE 4
000A 0000               .WORD   WAV4TB

000C 0000       V1IN:   .WORD   0               ; VOICE 1 INCREMENT (FREQUENCY PARAMETER)
000E 0000       V2IN:   .WORD   0               ; VOICE 2
0010 0000       V3IN:   .WORD   0               ; VOICE 3
0012 0000       V4IN:   .WORD   0               ; VOICE 4

0014 00         DUR:    .BYTE   0               ; DURATION COUNTER
0015 0000       NOTES:  .WORD   0               ; NOTES POINTER
0017 0002       SONGA:  .WORD   SONG            ; ADDRESS OF SONG
0019 0000       INCPT:  .WORD   0               ; POINTER FOR LOADING UP V1NT - V4NT
001B 0C00       INCA:   .WORD   V1IN            ; INITIAL VALUE OF INCPT
001D 5200       TEMPO:  .WORD   82              ; TEMPO CONTROL VALUE, TYPICAL VALUE FOR
                                                ; 3:4 TIME, 100 BEATS PER MINUTE, DUR=64
                                                ; DESIGNATES A QUARTER NOTE
0100                    .=      X'100           ; START PROGRAM CODE AT LOCATION 0100

                ;       MAIN MUSIC PLAYING PROGRAM

0100 A9FF       MUSIC:  LDA     #X'FF           ; SET PERIPHERAL A DATA DIRECTION
0102 8D0117             STA     DACDIR          ; REGISTER TO OUTPUT
0105 D8                 CLD                     ; INSURE BINARY ARITHMETIC
0106 A517               LDA     SONGA           ; INITIALIZE NOTES POINTER
0108 8515               STA     NOTES           ; TO BEGINNING OF SONG
010A A518               LDA     SONGA+1
010C 8516               STA     NOTES+1
010E A000       MUSIC1: LDY     #0              ; SET UP TO TRANSLATE 4 NOTE ID NUMBERS
0110 A51B               LDA     INCA            ; INTO FREQUENCY DETERMINING WAVEFORM TABLE
0112 8519               STA     INCPT           ; INCREMENTS AND STORE IN V1IN - V4IN
0114 B115               LDA     (NOTES),Y       ; GET DURATION FIRST
0116 F03C               BEQ     ENDSNG          ; BRANCH IF END OF SONG
0118 C901               CMP     #1              ; TEST IF END OF SONG TABLE SEGMENT
011A F029               BEQ     NXTSEG          ; BRANCH IF SO
011C 8514               STA     DUR             ; OTHERWOSE SAVE DURATION IN DUR
011E E615       MUSIC2: INC     NOTES           ; DOUBLE INCREMENT NOTES TO POINT TO THE
0120 D002               BNE     MUSIC3          ; NOTE ID OF THE FIRST VOICE
0122 E616               INC     NOTES+1
0124 B115       MUSIC3: LDA     (NOTES),Y       ; GET A NOTE ID NUMBER
0126 AA                 TAX                     ; INTO INDEX X
0127 B520               LDA     FRQTAB+1,X      ; GET LOW BYTE OF CORRESPONDING FREQUENCY
0129 9119               STA     (INCPT),Y       ; STORE INTO LOW BYTE OF VOICE INCREMENT
012B E619               INC     INCPT           ; INDEX TO HIGH BYTE
012D B51F               LDA     FRQTAB,X        ; GET HIGH BYTE OF FREQUENCY
012F 9119               STA     (INCPT),Y       ; STORE INTO HIGH BYTE OF VOICE INCREMENT
0131 E615               INC     NOTES           ; DOUBLE INCREMENT NOTES TO POINT TO THE
0133 D002               BNE     MUSIC4          ; NOTE ID OF THE NEXT VOICE
0135 E616               INC     NOTES+1
0137 E619       MUSIC4: INC     INCPT           ; INDEX TO NEXT VOICE INCREMENT
0139 A519               LDA     INCPT           ; TEST IF 4 VOICE INCREMENTS DONE
013B C914               CMP     #V4IN+2
013D D0E5               BNE     MUSIC3          ; LOOP IF NOT
013F 205701             JSR     PLAY            ; PLAY THIS GROUP OF NOTES
0142 4C0E01             JMP     MUSIC1          ; GO LOAD UP NEXT SET OF NOTES

0145 C8         NXTSEG: INY                     ; END OF SEGMENT, NEXT TWO BYTES POINT TO
0146 B115               LDA     (NOTES),Y       ; BEGINNING OF THE NEXT SEGMENT
0148 48                 PHA
0149 C8                 INY                     ; GET BOTH SEGMENT ADDRESS BYTES
014A B115               LDA     (NOTES),Y
014C 8516               STA     NOTES+1         ; THEN STORE IN NOTES POINTER
014E 68                 PLA
014F 8515               STA     NOTES
0151 4C0E01             JMP     MUSIC1          ; GO START INTERPRETING NEW SEGMENTT

0154 4C221C     ENDSNG: JMP     KIMMON          ; END OF SONG, RETURN TO MONITOR
                ;       4 VOICE PLAY SUBROUTINE
```

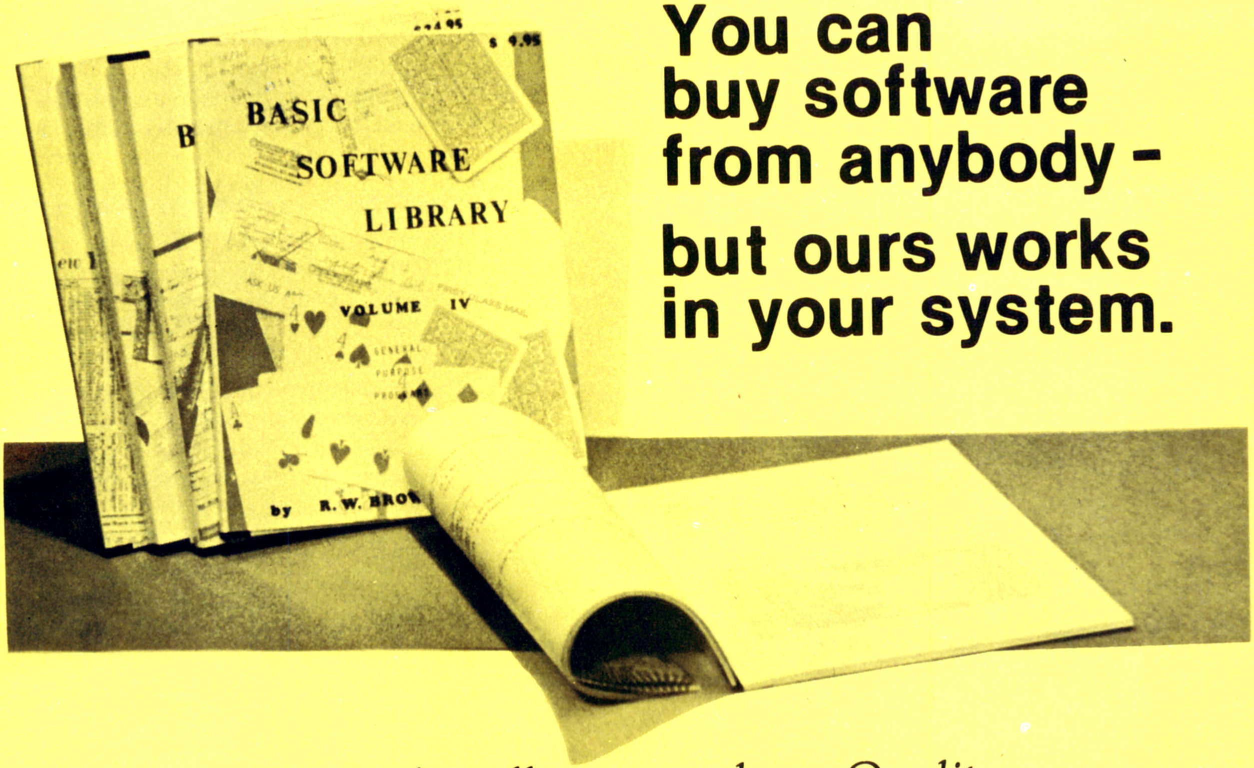
a sine wave with an amplitude dependent on the waveform of the resulting tone. Giving a different amplitude envelope to each harmonic is equivalent to smoothly changing the timbre during the note. The aliasing problem mentioned earlier can also be solved by simply omitting any harmonics that become too high in frequency.

Dynamic timbre variation can also be accomplished by a *digital filter* which does the same thing to a sampled waveform that a real inductance-capacitance filter does to a normal waveform. A digital filter is simply a subroutine which accepts a sample value as an argument and gives back a sample value which represents the filtered output. The equations used in the subroutine determine the filter type, and other arguments determine the cutoff frequency, Q, etc. This is a fascinating subject which deserves its own article.

What about other, unpitched sounds? They too can be handled with a few simple techniques. Most sounds in this category are based in part on random noise. In sampled form, random white noise with a uniform frequency spectrum is simply a stream of random numbers. For example, a fairly realistic snare drum sound may be generated by simply giving the proper amplitude envelope to pure white noise. Other types of drum sounds may be generated by using a digital filter to shape the frequency spectrum of the noise. A resonant type of digital filter would be used for tom-toms and similar semipitched drums, for example. A high pass filter is useful for simulating brush and cymbal sounds. An infinite number of variations are possible. This is one area where direct computation of sound waveforms really shines.

The sampling theorem works both ways also. Any waveform may be converted into digital samples with an analog to digital converter (ADC) with no loss of information. The only requirement is that the signal being sampled have no frequency components higher than half of the sampling frequency. This may be accomplished by passing the signal to be digitized through a sharp low pass filter prior to presenting it to the ADC. Once sound is in digitized form, literally anything may be done to it. A simple (in concept) application is intricate editing of the sound with a graphic display, light pen and large capacity disk. The sound may be analyzed into harmonic components and the result or a transformation of it applied to a synthesized sound. Again, this is an area that deserves its own article.

Application Software!



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Listing 2, continued:

```
0157 A000      PLAY:     LDY    #0             ; SET Y TO ZERO FOR STRAIGHT INDIRECT
0159 A61D                LDX    TEMPO          ; SET X TO TEMPO COUNT
                                               ; COMPUTE AND OUTPUT A COMPOSITE SAMPLE

015B 18        PLAY1:    CLC                   ; CLEAR CARRY
015C B101                LDA    (V1PT+1),Y     ; ADD UP 4 VOICE SAMPLES
015E 7104                ADC    (V2PT+1),Y     ; USING INDIRECT ADDRESSING THROUGH VOICE
0160 7107                ADC    (V3PT+1),Y     ; POINTERS INTO WAVEFORM TABLES
0162 710A                ADC    (V4PT+1),Y     ; STRAIGHT INDIRECT WHEN Y INDEX = 0
0164 8D0017              STA    X'1700         ; SEND SUM TO DIGITAL-TO-ANALOG CONVERTER
0167 A500                LDA    V1PT           ; ADD INCREMENTS TO POINTERS FOR
0169 650C                ADC    V1IN           ; THE 4 VOICES
016B 8500                STA    V1PT           ; FIRST FRACTIONAL PART
016D A501                LDA    V1PT+1
016F 650D                ADC    V1IN+1
0171 8501                STA    V1PT+1         ; THEN INTEGER PART
0173 A503                LDA    V2PT           ; VOICE 2
0175 650E                ADC    V2IN
0177 8503                STA    V2PT
0179 A504                LDA    V2PT+1
017B 650F                ADC    V2IN+1
017D 8504                STA    V2PT+1
017F A506                LDA    V3PT           ; VOICE 3
0181 6510                ADC    V3IN
0183 8506                STA    V3PT
0185 A507                LDA    V3PT+1
0187 6511                ADC    V3IN+1
0189 8507                STA    V3PT+1
018B A509                LDA    V4PT           ; VOICE 4
018D 6512                ADC    V4IN
018F 8509                STA    V4PT
0191 A50A                LDA    V4PT+1
0193 6513                ADC    V4IN+1
0195 850A                STA    V4PT+1
0197 CA                  DEX                   ; DECREMENT & CHECK TEMPO COUNT
0198 D008                BNE    TIMWAS         ; BRANCH TO TIME WASTE IF NOT RUN OUT
019A C614                DEC    DUR            ; DECREMENT & CHECK DURATION COUNTER
019C F00C                BEQ    ENDNOT         ; JUMP OUT IF END OF NOTE
019E A61D                LDX    TEMPO          ; RESTORE TEMPO COUNT
01A0 D0B9                BNE    PLAY1          ; CONTINUE PLAYING
01A2 D000      TIMWAS:   BNE    .+2            ; 3  WASTE 12 STATES
01A4 D000                BNE    .+2            ; 3
01A6 D000                BNE    .+2            ; 3
01A8 D0B1                BNE    PLAY1          ; 3  CONTINUE PLAYING
01AA 60        ENDNOT:   RTS                   ; RETURN
                                               ; TOTAL LOOP TIME = 114 STATES = 8770 HZ

01AB           P1END     =                     ; DEFINE BEGINNING ADDRESS FOR THIRD PART
                                               ; OF SONG TABLE
```

Sampled Waveform Example

It should be obvious by now that while these sampled waveform techniques are completely general and capable of high quality, there can be a great deal of computation required. Even the most powerful computers in existence would be hard pressed to compute samples for a significant piece of music with many voices and all subtleties implemented at a rate fast enough for direct output to a DAC and speaker. Typically the samples are computed at whatever rate the program runs and are saved on a mass storage device. After the piece has been "computed," a playback program retrieves the samples and sends them to the DAC at a uniform high rate.

Most microprocessors are fast enough to do a limited amount of sampled waveform computation in real time. The 6502 is one of the best 8 bit machines in this capacity due to its indexed and indirect addressing modes and its overall high speed. The example program shown in listing 2 has the inherent capability to generate four simultaneous voices, each with a different waveform and volume level. In order to make the whole thing fit in a basic KIM-1, however, only one waveform table is actually used.

This program could probably be considered as a variation of the timed loop technique, since the sample rate is determined by the execution time of a particular loop. The major differences are that all of the instructions in the loop perform an essential function and that the loop time is constant regardless of the notes being played. Using the program as shown on a full speed (1.0 MHz) 6502 gives a sample rate of 8.77 kHz, which results in a useful upper frequency limit of 3 kHz. The low pass filter in figure 7 coupled with the DAC in figure 3 and audio system or amplifier in figure 8 are all the specialized hardware necessary to run the program with full 4 part harmony.

The program consists of two major routines: MUSIC and PLAY. MUSIC steps through the list of notes in the song table and sets up DUR and V1IN thru V4IN for the PLAY routine. PLAY simultaneously plays the four notes specified by V1IN thru V4IN for the time period specified by DUR. Another variable, TEMPO, in page zero controls the overall tempo of the music independently of the durations specified in the song table. The waveform tables for the four voices are located at WAV1TB thru WAV4TB and require 256 bytes (one memory page) each. The actual waveform samples stored in the table have already been scaled so that when four of them are added up there is no possibility of overflow.

The song table has an entry for each musical "event" in the piece. An entry requires five bytes, the first of which is a duration parameter. By suitable choice of the TEMPO parameter in page 0, "round" (in the binary sense) numbers may be used for duration parameters of common note durations. A duration parameter of 0 signals the end of the song, in which case the program returns to the monitor. A duration parameter of 1 is used to specify a break in the sequential flow of the song table. In this case the next two bytes point to the continuation of the table elsewhere in memory. This feature was necessary to deal with the fragmented memory of the KIM-1, but has other uses as well. All other possible duration values are taken literally and are followed by four bytes which identify the notes to be played by each voice. Each note ID points to a location in the note frequency table which in turn contains a 2 byte frequency parameter for that note which is placed in V1IN thru V4IN.

The PLAY routine is optimized for speed,

Bet on Quay microcomputers, components, and software. They're winners.

See Quay products. Booths 341 G
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'77 Show, August 27, 28
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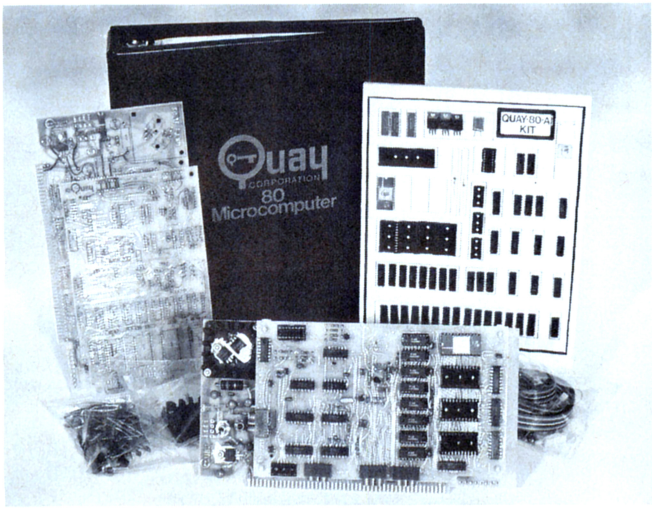
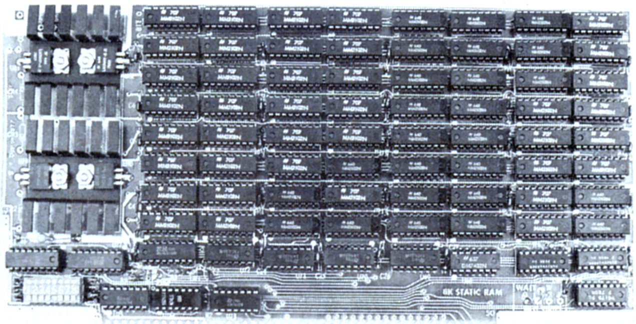
City, N.J.



Bet 1. Quay 80AI.-CPU, monitor I/O.
For beginners, Quay 80AI is a sure thing. It's a **stand alone** microcomputer in a kit. Assemble it. Plug it into your power supply. Hook on a terminal. And go. Quay 80AI uses the powerful Z80 microprocessor with a 2.5 Mhz clock, it's also S100 bus compatible and fast, efficient, expandable and economical. You can't lose.

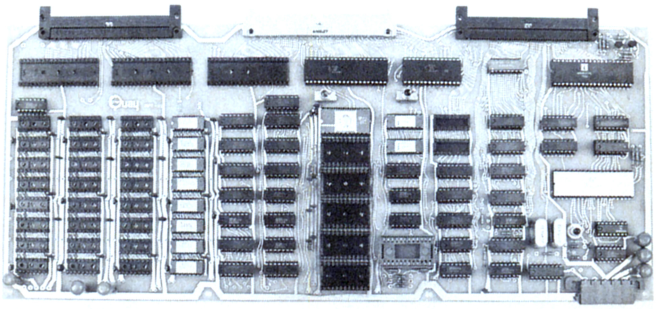


Bet 2. Quay 80SMB. 8K memory.
Here's 8K of static RAM memory in a kit. You'll never find a more economical way to added memory. Great for expanding the capacity of Quay 80AI or any other S100 microcomputer.

Bet 3. Quay 80MBPS. Motherboard/power supply.
When you're expanding, looking at bigger games; the Quay 80 MBPS 12-slot motherboard with or without a power supply is best for you. Gives you plenty of room. And when the time comes, you can put it into a dynamite Quay chassis (Bet 4).

Bet 4. Quay 80C. Chassis.
If you've grown with Quay, component by component, you'll reach the point where you'll want this fine chassis. It turns a jumble of hardware into a compact, good-looking, functiontionally-efficient system. It gives your high-quality components the look of class.

Bet 5. Quay 8000. System.
The Quay 8000 is a complete microcomputer system consisting of the Quay 80AI (**Bet 1**), the Quay 80SMB (**Bet 2**), Quay 80MBPS (**Bet 3**), Quay 80C (**Bet 4**), and Quay 80 4K Basic (**Bet 7**). If you want a complete package with plenty of power and Basic, this is it. It's the best system you can buy for the dollars (under 1K bucks). You're in operation with a complete top-quality system. (It's less expensive to buy the complete system than to buy the individual components.)



Bet 6. Quay 90MPS. OEM microcomputer.
The Quay 90MPS is a complete OEM microcomputer system on a single board. It's designed for OEM use or for the highly sophisticated hobbyist. Quay 90MPS comes completely assembled and tested. It uses the Z80 microprocessor, has 6K of memory (expandable to 65K), a 2.5 Mhz clock with a 4Mhz clock option. This is the big time.

Bet 7. Quay 80AI and Quay 90MPS software.
Quay has available for its systems the following software in **Basic:** ■ 2KB on UV Prom for 80AI or 90MPS ■ 4KB on UV Prom for 90 MPS ■ 4 KB on cassette tape for 80AI or 90MPS ■ 10KB on cassette tape for 90MPS.

Bet 8. Quay coming events.
Available soon: an Assembler Editor package and Business Applications for 10K Basic. Get on the Quay mailing list so when they're ready you'll be among the first to know.

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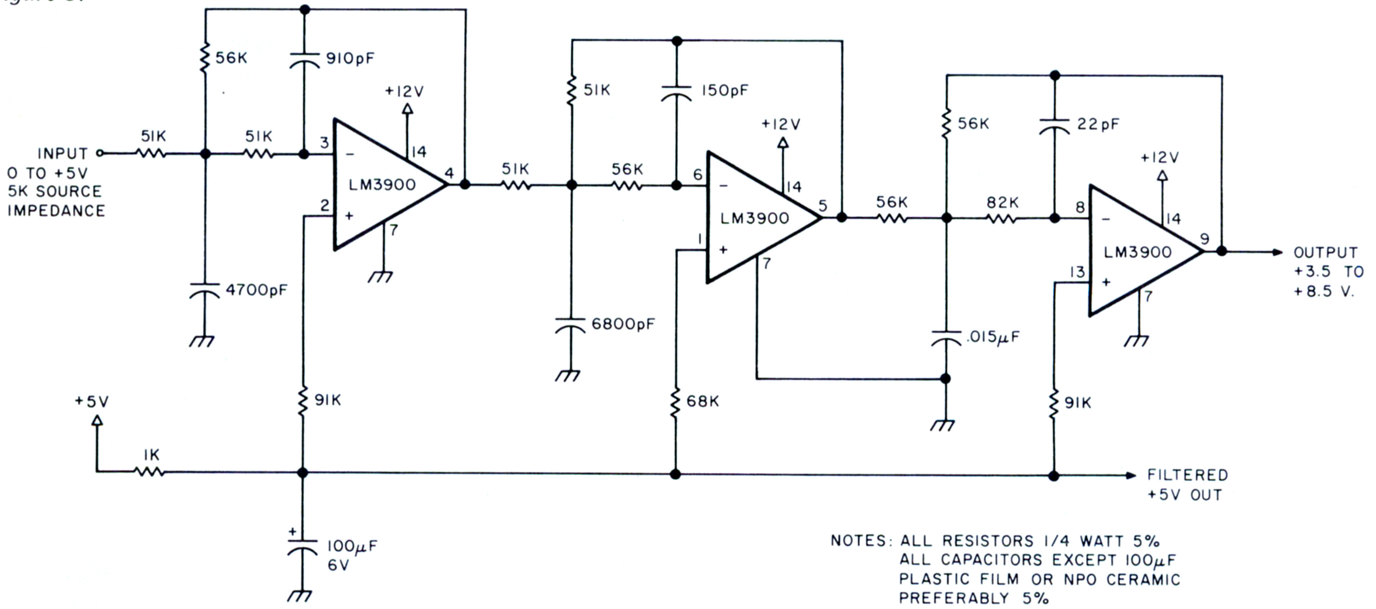
Figure 7: A sharp low pass filter with 3 kHz cutoff. This circuit is used to filter out the high frequency distortion illustrated in figure 5.



```
                   ;        NOTE FREQUENCY TABLE FOR 8.772 KHZ SAMPLE RATE
                   ;        RANGE FROM C2 (65.41 HZ) TO C6 (1046.5 HZ)
                   ;                                  ID NOTE  FREQ.  INCR.
001F 0000          FRQTAB:  .BYTE  0,0           ;  0  SILENCE
0021 01E9                   .BYTE  1,233         ;  2  C2    65.405  1.9089
0023 0206                   .BYTE  2,6           ;  4  C2#   69.295  2.0224
0025 0225                   .BYTE  2,37          ;  6  D2    73.415  2.1427
0027 0245                   .BYTE  2,69          ;  8  D2#   77.783  2.2701
0029 0268                   .BYTE  2,104         ; 10  E2    82.408  2.4051
002B 028C                   .BYTE  2,140         ; 12  F2    87.308  2.5481
002D 02B3                   .BYTE  2,179         ; 14  F2#   92.498  2.6996
002F 02DC                   .BYTE  2,220         ; 16  G2    97.998  2.8601
0031 0308                   .BYTE  3,8           ; 18  G2#   103.83  3.0302
0033 0336                   .BYTE  3,54          ; 20  A2    110.00  3.2104
0035 0367                   .BYTE  3,103         ; 22  A2#   116.54  3.4013
0037 039A                   .BYTE  3,154         ; 24  B2    123.47  3.6035
0039 03D1                   .BYTE  3,209         ; 26  C3    130.81  3.8178
003B 040B                   .BYTE  4,11          ; 28  C3#   138.59  4.0448
003D 0449                   .BYTE  4,73          ; 30  D3    146.83  4.2854
003F 048A                   .BYTE  4,138         ; 32  D3#   155.57  4.5402
0041 04CF                   .BYTE  4,207         ; 34  E3    164.82  4.8102
0043 0519                   .BYTE  5,25          ; 36  F3    174.62  5.0962
0045 0566                   .BYTE  5,102         ; 38  F3#   185.00  5.3992
0047 05B8                   .BYTE  5,184         ; 40  G3    196.00  5.7203
0049 060F                   .BYTE  6,15          ; 42  G3#   207.65  6.0604
004B 066C                   .BYTE  6,108         ; 44  A3    220.00  6.4208
004D 06CD                   .BYTE  6,205         ; 46  A3#   233.08  6.8026
004F 0735                   .BYTE  7,53          ; 48  B3    246.94  7.2071
0051 07A3                   .BYTE  7,163         ; 50  C4    261.62  7.6356
0053 0817                   .BYTE  8,23          ; 52  C4#   277.18  8.0897
0055 0892                   .BYTE  8,146         ; 54  D4    293.66  8.5707
0057 0915                   .BYTE  9,21          ; 56  D4#   311.13  9.0804
0059 099F                   .BYTE  9,159         ; 58  E4    329.63  9.6203
005B 0A31                   .BYTE  10,49         ; 60  F4    349.23  10.1924
005D 0ACC                   .BYTE  10,204        ; 62  F4#   369.99  10.7984
005F 0B71                   .BYTE  11,113        ; 64  G4    391.99  11.4405
0061 0C1F                   .BYTE  12,31         ; 66  G4#   415.30  12.1208
0063 0CD7                   .BYTE  12,215        ; 68  A4    440.00  12.8416
0065 0D9B                   .BYTE  13,155        ; 70  A4#   466.16  13.6052
0067 0E6A                   .BYTE  14,106        ; 72  B4    493.88  14.4142
0069 0F45                   .BYTE  15,69         ; 74  C5    523.24  15.2713
006B 102E                   .BYTE  16,46         ; 76  C5#   554.36  16.1794
006D 1124                   .BYTE  17,36         ; 78  D5    587.32  17.1414
006F 1229                   .BYTE  18,41         ; 80  D5#   622.26  18.1607
0071 133E                   .BYTE  19,62         ; 82  E5    659.26  19.2406
0073 1462                   .BYTE  20,98         ; 84  F5    698.46  20.3847
0075 1599                   .BYTE  21,153        ; 86  F5#   739.98  21.5969
0077 16E2                   .BYTE  22,226        ; 88  G5    783.98  22.8811
0079 183E                   .BYTE  24,62         ; 90  G5#   830.60  24.2417
007B 19AF                   .BYTE  25,175        ; 92  A5    880.00  25.6831
007D 1B36                   .BYTE  27,54         ; 94  A5#   932.32  27.2103
007F 1CD4                   .BYTE  28,212        ; 96  B5    987.76  28.8283
0081 1E8B                   .BYTE  30,139        ; 98  C6    1046.5  30.5426
0083            POEND    =        .              ; DEFINE BEGINNING ADDRESS FOR SECOND PART
                                                 ; OF SONG TABLE
```

Table 3: Note frequency table used in conjunction with listing 2. This table is for a sample rate of 8.772 kHz. The range of the notes used is from 65.41 Hz (for C2) to 1046.5 Hz (for C6).

because its loop time determines the sample rate. Essentially, the routine maintains four pointers (V1PT thru V4PT) to the four waveform tables. Each pointer consists of three bytes in order of increasing significance. The first byte is the "fractional part" of the pointer, and the second byte is the integer part which is also the lower half of an address in the waveform table. The third byte is the upper address which normally remains constant. Waveform table lookup is considerably simplified by using the indirect addressing mode of the 6502 with these pointers. Note that the fractional part of the pointer is ignored when the table lookup takes place, since interpolation is much too slow for a real time routine.

During each sample, waveform table entries for each voice are fetched, added up, and sent to the digital to analog converter output port. Then the increment (VxIN) is added (double precision) to each pointer (VxPT). Wraparound from the end of a waveform table to the beginning is automatically taken care of due to the fact that the table occupies a full memory page. Finally, the tempo counter is decremented and checked. If the tempo counter is zero, it is restored and the duration counter is decremented and checked. If it is also zero the note is finished and PLAY returns. The net result is that TxD samples are computed and sent out for the event, where T is the tempo parameter and D is the duration parameter. Note that, unlike the earlier timed loop example, there is no interaction between the duration parameter and the note frequencies being played.

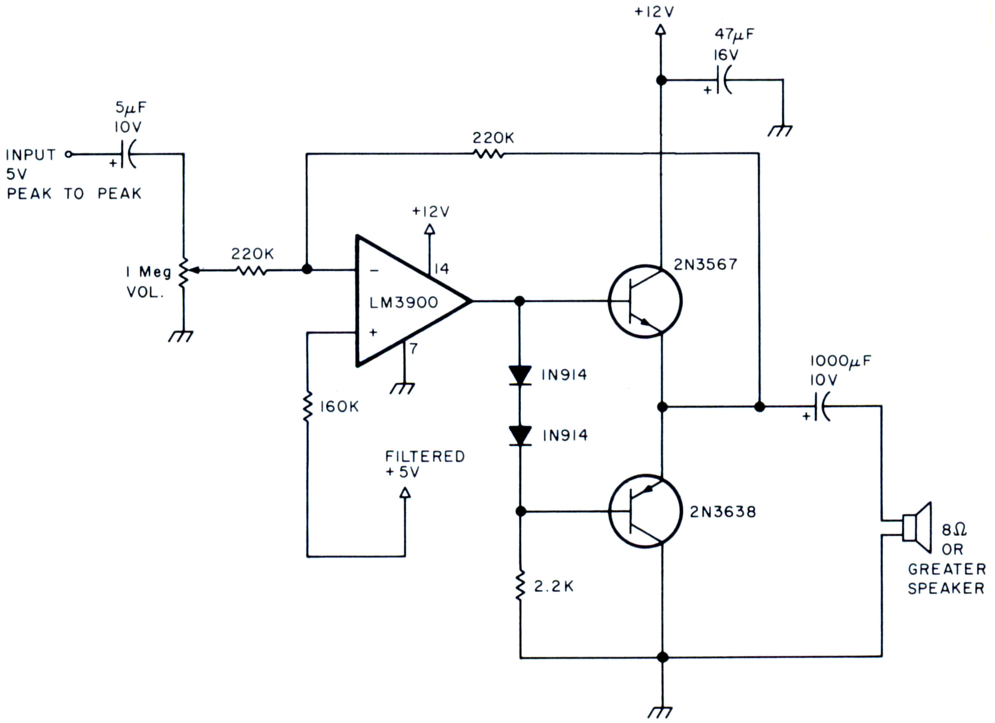


Figure 8. An inexpensive, wide band low power audio amplifier. This circuit, when coupled with the circuits in figures 3 and 7, is all the experimenter needs to create music with his or her microprocessor.

```
                     ;        SONG TABLE
                     ;        EACH MUSICAL EVENT CONSISTS OF 5 BYTES
                     ;        THE FIRST IS THE DURATION OF THE EVENT IN UNITS ACCORDING TO
                     ;        THE VALUE OF "TEMPO", ZERO DENOTES THE END OF THE SONG.
                     ;        THE NEXT 4 BYTES CONTAIN THE NOTE ID OF THE 4 VOICES, 1 THROUGH
                     ;        4.  0 INDICATES SILENCE FOR THE VOICE.

0200                          .=      X'200          ; START SONG AT 0200

                     ;        SONG TABLE FOR THE STAR SPANGLED BANNER BY FRANCIS SCOTT KEY
                     ;        AND J. STAFFORD SMITH
                     ;        DURATION COUNT = 64 FOR QUARTER NOTE

0200 604A000032  SONG:        .BYTE  96,74,0,0,50            ; 3/8    C5                C4    1
0205 104400002C               .BYTE  16,68,0,0,44            ; 1/16   A4                A3
020A 4040000024               .BYTE  64,64,0,0,36            ; 1/4    G4                F3    2
020F 4044000024               .BYTE  64,68,0,0,36            ; 1/4    A4                F3
0214 404A000022               .BYTE  64,74,0,0,34            ; 1/4    C5                E3
0219 80544E441E               .BYTE  128,84,78,68,30         ; 1/2    F5    D5    A4    D3    3
021E 305C52441C               .BYTE  48,92,82,68,28          ; 3/16   A5    E5    A4    C#3
0223 105800401C               .BYTE  16,88,0,64,28           ; 1/16   G5          G4    C#3
0228 4054003C1E               .BYTE  64,84,0,60,30           ; 1/4    F5          F4    D3    4
022D 4044003C1E               .BYTE  64,68,0,60,30           ; 1/4    A4          F4    D3
0232 4048403C28               .BYTE  64,72,64,60,40          ; 1/4    B4    G4    F4    G3
0237 804A403A32               .BYTE  128,74,64,58,50         ; 1/2    C5    G4    E4    C4    5
023C 204A000032               .BYTE  32,74,0,0,50            ; 1/8    C5                C4
0241 204A000032               .BYTE  32,74,0,0,50            ; 1/8    C5                C4
0246 605C544424               .BYTE  96,92,84,68,36          ; 3/8    A5    F5    A4    F3    6
024B 2058004028               .BYTE  32,88,0,64,40           ; 1/8    G5          G4    G3
0250 4054003C2C               .BYTE  64,84,0,60,44           ; 1/4    F5          F4    A3
0255 80524A4032               .BYTE  128,82,74,64,50         ; 1/2    E5    C5    G4    C4    7
025A 304E46002E               .BYTE  48,78,70,0,46           ; 3/16   D5    B@4         B@3
025F 10524A402E               .BYTE  16,82,74,64,46          ; 1/16   E5    C5    G4    B@3
0264 40544A442C               .BYTE  64,84,74,68,44          ; 1/4    F5    C5    A4    A3    8
0269 405400003C               .BYTE  64,84,0,0,60            ; 1/4    F5                F4
026E 404A000032               .BYTE  64,74,0,0,50            ; 1/4    C5                C4
0273 404400002C               .BYTE  64,68,0,0,44            ; 1/4    A4                A3    9
0278 403C000024               .BYTE  64,60,0,0,36            ; 1/4    F4                F3
027D 304A000032               .BYTE  48,74,0,0,50            ; 3/16   C5                C4
0282 104400002C               .BYTE  16,68,0,0,44            ; 1/16   A4                A3
0287 403C000024               .BYTE  64,60,0,0,36            ; 1/4    F4                F3    10
028C 4044000024               .BYTE  64,68,0,0,36            ; 1/4    A4                F3
0291 404A000022               .BYTE  64,74,0,0,34            ; 1/4    C5                E3
0296 80544E441E               .BYTE  128,84,78,68,30         ; 1/2    F5    D5    A4    D3    11
029B 305C52441C               .BYTE  48,92,82,68,28          ; 3/16   A5    E5    A4    C#3
```

Table 4: This song table is an encoding of "The Star Spangled Banner" in 4 part harmony which is used by the program in listing 2. Each musical event in the table consists of five bytes. The first byte represents the duration of the event in units, according to the value of the "tempo" (0 denotes the end of the song). The next four bytes contain the note identifications of the four voices (0 indicates silence for the voice).

How does it sound? With the waveform table shown and a reasonably good speaker system, the result sounds very much like an electronic organ, such as a Hammond. There is a noticeable background noise level due to compromises such as prescaled waveforms and lack of interpolation in the tables, but it is not objectionable. The pitches are very accurate, but there is some beating on chords due to compromises inherent in the standard equally tempered musical scale. Also there are noticeable clicks between notes due to the time taken by the MUSIC routine to set up the next set of notes. All in all the program makes a good and certainly inexpensive basis for the "family music application" mentioned earlier.

Synthesizer Control Techniques

So far we have discussed techniques in which the computer itself generates the sound. It is also possible to interface a computer to specialized sound generation hardware and have it act as a *control* element.

The most obvious kind of equipment to control is the standard, modular, voltage controlled sound synthesizer. Since the interface characteristics of nearly all synthesizers and modules are standardized, a computer interface to such equipment could be used with nearly any synthesizer in common use.

Generally speaking, the function of a voltage controlled module is influenced by one or more DC control voltages. These are usually assumed to be in the range of 0 to +10 volts, although some modules will have a predictable response to negative voltages as well. In a voltage controlled oscillator, for example, the output frequency is determined by a control voltage. For typical tuning, 0 V would correspond to 16 Hz (a very low C), and the frequency would increase one volt per octave for higher voltages. Thus, +4 V would produce middle C, and the maximum input of +10 V would produce a nearly inaudible 16.4 kHz. A typical oscillator module has two or three control inputs and a number of outputs. The voltages at the inputs are internally summed to form the effective control value (useful for injecting vibrato), and the outputs provide several different waveforms simultaneously.

Table 4, continued:

```
02A0 105800401C       .BYTE  16,88,0,64,28       ; 1/16    G5          G4    C#3
02A5 4054003C1E       .BYTE  64,84,0,60,30       ; 1/4     F5          F4    D3    12
02AA 4044003C1E       .BYTE  64,68,0,60,30       ; 1/4     A4          F4    D3
02AF 4048403C28       .BYTE  64,72,64,60,40      ; 1/4     B4    G4    F4    G3
02B4 804A403A32       .BYTE  128,74,64,58,50     ; 1/2     C5    G4    E4    C4    13
02B9 204A000032       .BYTE  32,74,0,0,50        ; 1/8     C5                C4
02BE 204A000032       .BYTE  32,74,0,0,50        ; 1/8     C5                C4
02C3 605C544424       .BYTE  96,92,84,68,36      ; 3/8     A5    F5    A4    F3    14
02C8 2058004028       .BYTE  32,88,0,64,40       ; 1/8     G5          G4    G3
02CD 2054003C2C       .BYTE  32,84,0,60,44       ; 1/8     F5          F4    A3
02D2 80524A4032       .BYTE  128,82,74,64,50     ; 1/2     E5    C5    G4    C4    15
02D7 304E46002E       .BYTE  48,78,70,0,46       ; 3/16    D5    B@4         B@3
02DC 10524A402E       .BYTE  16,82,74,64,46      ; 1/16    E5    C5    G4    B@3
02E1 40544A442C       .BYTE  64,84,74,68,44      ; 1/4     F5    C5    A4    A3    16
02E6 405400003C       .BYTE  64,84,0,0,60        ; 1/4     F5                F4
02EB 404A000032       .BYTE  64,74,0,0,50        ; 1/4     C5                C4
02F0 404400002C       .BYTE  64,68,0,0,44        ; 1/4     A4                A3    17
02F5 403C000024       .BYTE  64,60,0,0,36        ; 1/4     F4                F3
02FA 01               .BYTE  1                   ; DEFINE END OF THIS SEGMENT
02FB 8300             .WORD  P0END               ; ADDRESS OF BEGINNING OF NEXT
                                                 ; SEGMENT
0083                  .=     P0END               ; ORG AT END OF PAGE 0 CODE
0083 305C544428       .BYTE  48,92,84,68,40      ; 3/16    A5    F5    A4    G3
0088 105C544428       .BYTE  16,92,84,68,40      ; 1/16    A5    F5    A4    G3
008D 405C544424       .BYTE  64,92,84,68,36      ; 1/4     A5    F5    A4    F3    18
0092 405E544628       .BYTE  64,94,84,70,40      ; 1/4     B@5   F5    B@4   G3
0097 4062544A2C       .BYTE  64,98,84,74,44      ; 1/4     C6    F5    C5    A3
009C 8062544A2C       .BYTE  128,98,84,74,44     ; 1/2     C6    F5    C5    A3    19
00A1 205E544628       .BYTE  32,94,84,70,40      ; 1/8     B@5   F5    B@4   G3
00A6 205C54442C       .BYTE  32,92,84,68,44      ; 1/8     A5    F5    A4    A3
00AB 4058524032       .BYTE  64,88,82,64,50      ; 1/4     G5    E5    G4    C4    20
00B0 405C54443C       .BYTE  64,92,84,68,60      ; 1/4     A5    F5    A4    F4
00B5 405E524640       .BYTE  64,94,82,70,64      ; 1/4     B@5   E5    B@4   G4
00BA 805E58461A       .BYTE  128,94,88,70,26     ; 1/2     B@5   G5    B@4   C3    21
00BF 405E52461A       .BYTE  64,94,82,70,26      ; 1/4     B@5   E5    B@4   C3
00C4 605C4A4424       .BYTE  96,92,74,68,36      ; 3/8     A5    C5    A4    F3    22
00C9 20584A4028       .BYTE  32,88,74,64,40      ; 1/8     G5    C5    G4    G3
00CE 40544A3C2C       .BYTE  64,84,74,60,44      ; 1/4     F5    C5    F4    A3
00D3 80524A4032       .BYTE  128,82,74,64,50     ; 1/2     E5    C5    G4    C4    23
00D8 204E00362E       .BYTE  32,78,0,54,46       ; 1/8     D5          D4    B@3
00DD 20524A3A2E       .BYTE  32,82,74,58,46      ; 1/8     E5    C5    E4    B@3
00E2 40544A3C2C       .BYTE  64,84,74,60,44      ; 1/4     F5    C5    F4    A3    24
00E7 40443C0036       .BYTE  64,68,60,0,54       ; 1/4     A4    F4          D4
00EC 01               .BYTE  1                   ; DEFINE END OF THIS SEGMENT
00ED AB01             .WORD  P1END               ; ADDRESS OF BEGINNING OF NEXT
                                                 ; SEGMENT
01AB                  .=     P1END               ; ORG AT END OF PAGE 1 CODE
01AB 4048403C28       .BYTE  64,72,64,60,40      ; 1/4     B4    G4    F4    G3
01B0 804A403A1A       .BYTE  128,74,64,58,26     ; 1/2     C5    G4    E4    C3    25
01B5 404A000032       .BYTE  64,74,0,0,50        ; 1/4     C5                C4
01BA 40544A4424       .BYTE  64,84,74,68,36      ; 1/4     F5    C5    A4    F3    26
01BF 4054464028       .BYTE  64,84,70,64,40      ; 1/4     F5    B@4   G4    G3
01C4 20544A442C       .BYTE  32,84,74,68,44      ; 1/8     F5    C5    A4    A3
01C9 20524A442C       .BYTE  32,82,74,68,44      ; 1/8     E5    "     "     "
01CE 404E463C2E       .BYTE  64,78,70,60,46      ; 1/4     D5    B@4   F4    B@3   27
01D3 404E463C2E       .BYTE  64,78,70,60,46      ; 1/4     D5    B@4   F4    B@3
01D8 404E4A3E2C       .BYTE  64,78,74,62,44      ; 1/4     D5    C5    F#4   A3
01DD 4058464028       .BYTE  64,88,70,64,40      ; 1/4     G5    B@4   G4    G3    28
01E2 205E460028       .BYTE  32,94,70,0,40       ; 1/8     B@5   B@4         G3
01E7 205C44002C       .BYTE  32,92,68,0,44       ; 1/8     A5    A4          A3
01EC 205840002E       .BYTE  32,88,64,0,46       ; 1/8     G5    G4          B@3
01F1 01               .BYTE  1                   ; DEFINE END OF THIS SEGMENT
01F2 8017             .WORD  AUXRAM              ; ADDRESS OF BEGINNING OF NEXT
                                                 ; SEGMENT (IN 6530 RAM)
1780                  .=     AUXRAM              ; ORG AT BEGINNING OF 6530 RAM
1780 20543C0030       .BYTE  32,84,60,0,48       ; 1/8     F5    F4          B3
1785 40544A4432       .BYTE  64,84,74,68,50      ; 1/4     F5    C5    A4    C4    29
178A 40524A401A       .BYTE  64,82,74,64,26      ; 1/4     E5    C5    G4    C3
178F 204A000032       .BYTE  32,74,0,0,50        ; 1/8     C5                C4
1794 204A00002E       .BYTE  32,74,0,0,46        ; 1/8     C5                B@3
1799 60544A442C       .BYTE  96,84,74,68,44      ; 3/8     F5    C5    A4    A3    30
179E 2058004032       .BYTE  32,88,0,64,50       ; 1/8     G5          G4    C4
17A3 205C004440       .BYTE  32,92,0,68,64       ; 1/8     A5          A4    G4
17A8 205E004640       .BYTE  32,94,0,70,64       ; 1/8     B@5         B@4   G4
17AD 80625C5444       .BYTE  128,98,92,84,68     ; 1/2     C6    A5    F5    A4    31
17B2 20544E4436       .BYTE  32,84,78,68,54      ; 1/8     F5    D5    A4    D4
17B7 2058484034       .BYTE  32,88,72,64,52      ; 1/8     G5    B4    G4    D@4
17BC 605C544A32       .BYTE  96,92,84,74,50      ; 3/8     A5    F5    C5    C4    32
17C1 205E544E32       .BYTE  32,94,84,78,50      ; 1/8     B@5   F5    D5    C4
17C6 4058524632       .BYTE  64,88,82,70,50      ; 1/4     G5    E5    B@4   C4
17CB 80544A443C       .BYTE  128,84,74,68,60     ; 1/2     F5    C5    A4    F4    33
17D0 00               .BYTE  0                   ; END OF PIECE
```

A voltage controlled amplifier has as a minimum a signal input, a control input, and a signal output. The voltage at the control input determines the gain from the signal input to the signal output. In a typical setting, +8 V would correspond to unity (0 db) gain, with lower voltages decreasing the gain by 10 db per volt.

Many other voltage controlled devices have been developed during the approximately 12 year history of this field. In order to play music, the modules are first "patched" together with patch cords (like old style telephone switchboards) according to the desired sound characteristics. Manually operated control voltage sources such as potentiometers, joysticks and specialized organ-like keyboards are then manipulated by the player. The music is generally monotonic due to difficulties in the control elements (now being largely overcome). Multitrack tape recorders are universally utilized to produce the results heard on recordings such as Walter Carlos's *Switched on Bach*.

A useful computer interface to a synthesizer can be accomplished with nothing more than a handful of digital to analog and optionally analog to digital converters. The DACs would be used to generate control voltages under program control and the ADCs would allow operator input from the keyboard, for example, to be stored. Since control voltages vary slowly compared to the actual sound waveforms, real time control of a number of synthesizer modules is possible with the average microprocessor. Due to the large number of DACs required and the relatively slow speeds necessary, a multiplexing scheme using one DAC and a number of sample and hold amplifiers is appropriate. The home builder should be able to achieve costs as low as $2 per channel for a 32 channel, 12 bit unit capable of controlling a fairly large synthesizer.

The routing of patch cords can also be computerized. A matrix of reed relays or possibly CMOS bilateral switches interfaced to the computer might be used for this task. The patches used for some contemporary synthesizer sounds resemble the program patch boards of early computers and thus are difficult and time consuming to set up and verify. With computer controlled patching, a particular setup may be recalled and set up in milliseconds, thus enhancing real time performance as well as reducing the need for a large number of different modules.

Other musical instruments may be interfaced as well. One well-published feat is an interface between a PDP-8 computer and a fair sized pipe organ. There are doubtless several interfaces to electronic organs in existence also. Even piano mechanisms can be activated, as noted elsewhere in this issue.

Recently, specialized music peripherals have appeared, usually oriented toward the S-100 (Altair) bus. In some cases these are digital equivalents of analog modules of similar function. For example, a variable frequency oscillator may be implemented using a divide-by-N counter driven by a crystal clock. The output frequency is determined by the value of N loaded into a register in the device, much as a control voltage affects a voltage controlled oscillator. Such an approach bypasses the frequency drift problems and interfacing expense of analog modules. The biggest advantage, however, is availability of advanced functions not feasible with analog modules.

One of these is a programmable waveform. A small memory in the peripheral holds the waveform (either as individual sample values or Fourier coefficients), which can be changed by writing in a new waveform under program control. Another advantage is that *time multiplexing* of the logic is usually possible. This means that one set of logic may simulate the function of several digital oscillators simultaneously, thus reducing the per oscillator cost substantially. Actually, such a digital oscillator may be nothing more than a hardware implementation of the PLAY routine mentioned earlier.

Digital/analog hybrids are also possible. The speech synthesizer module produced by Computalker Consultants, for example, combines a programmable oscillator, several programmable amplifiers and filters, white noise generator, and programmable switching on one board. Although designed for producing speech, its completely programmable nature gives it significant musical potential, particularly in vocals.

How do these various control techniques compare with the direct waveform computation techniques discussed earlier? A definite advantage of course is real time playing of the music. Another advantage is simpler programming, since sound generation has already been taken care of. However, the number of voices and complexity of subtle variations is directly related to the quantity of synthesizer modules available.

```
                 ;       WAVEFORM TABLE
                 ;       EXACTLY ONE PAGE LONG ON A PAGE BOUNDARY
                 ;       MAXIMUM VALUE OF AN ENTRY IS 63 DECIMAL OR 3F HEX TO AVOID
                 ;       OVERFLOW WHEN 4 VOICES ARE ADDED UP

0300                     .=     X'300        ; START WAVEFORM TABLE AT 0300

0300             WAV1TB  =      .            ; VOICE 1 WAVEFORM TABLE
0300             WAV2TB  =      .            ; VOICE 2 WAVEFORM TABLE
0300             WAV3TB  =      .            ; VOICE 3 WAVEFORM TABLE
0300             WAV4TB  =      .            ; VOICE 4 WAVEFORM TABLE
                                             ; NOTE THAT ALL 4 VOICES USE THIS TABLE DUE
                                             ; TO LACK OF RAM IN BASIC KIM-1

                 ;         FUNDAMENTAL AMPLITUDE  1.0 (REFERENCE)
                 ;         SECOND HARMONIC .5, IN PHASE WITH FUNDAMENTAL
                 ;         THIRD HARMONIC .5, 90 DEGREES LEADING PHASE

0300 3334353636          .BYTE  X'33,X'34,X'35,X'36,X'36,X'37,X'38,X'39
0305 373839
0308 393A3A3B3B          .BYTE  X'39,X'3A,X'3A,X'3B,X'3B,X'3B,X'3C,X'3C
030D 3B3C3D
0310 3C3C3C3C3C          .BYTE  X'3C,X'3C,X'3C,X'3C,X'3C,X'3C,X'3C,X'3C
0315 3C3C3C
0318 3C3C3C3B3B          .BYTE  X'3C,X'3C,X'3C,X'3B,X'3B,X'3B,X'3B,X'3B
031D 3B3B3B
0320 3A3A3A3A3A          .BYTE  X'3A,X'3A,X'3A,X'3A,X'3A,X'3A,X'39,X'39
0325 3A3939
0328 3939393939          .BYTE  X'39,X'39,X'39,X'39,X'39,X'39,X'39,X'39
032D 393939
0330 3A3A3A3A3A          .BYTE  X'3A,X'3A,X'3A,X'3A,X'3A,X'3B,X'3B,X'3B
0335 3B3B3B
0338 3B3C3C3C3D          .BYTE  X'3B,X'3C,X'3C,X'3C,X'3D,X'3D,X'3D,X'3D
033D 3D3D3D
0340 3E3E3E3E3F          .BYTE  X'3E,X'3E,X'3E,X'3E,X'3F,X'3F,X'3F,X'3F
0345 3F3F3F
0348 3F3F3F3F3F          .BYTE  X'3F,X'3F,X'3F,X'3F,X'3F,X'3F,X'3F,X'3F
034D 3F3F3F
0350 3E3E3E3D3D          .BYTE  X'3E,X'3E,X'3E,X'3D,X'3D,X'3C,X'3C,X'3B
0355 3C3C3B
0358 3B3A393838          .BYTE  X'3B,X'3A,X'39,X'38,X'38,X'37,X'36,X'35
035D 373635
0360 3433323130          .BYTE  X'34,X'33,X'32,X'31,X'30,X'2F,X'2E,X'2D
0365 2F2E2D
0368 2C2B2A2928          .BYTE  X'2C,X'2B,X'2A,X'29,X'28,X'27,X'26,X'25
036D 272625
0370 2423222121          .BYTE  X'24,X'23,X'22,X'21,X'21,X'20,X'1F,X'1F
0375 201F1F
0378 1E1E1D1D1D          .BYTE  X'1E,X'1E,X'1D,X'1D,X'1D,X'1D,X'1C,X'1C
037D 1D1C1C
0380 1C1C1D1D1D          .BYTE  X'1C,X'1C,X'1D,X'1D,X'1D,X'1D,X'1D,X'1E
0385 1D1D1E
0388 1E1F1F2020          .BYTE  X'1E,X'1F,X'1F,X'20,X'20,X'21,X'21,X'22
038D 212122
0390 2323242425          .BYTE  X'23,X'23,X'24,X'24,X'25,X'26,X'26,X'27
0395 262627
0398 2828292929          .BYTE  X'28,X'28,X'29,X'29,X'29,X'2A,X'2A,X'2B
039D 2A2A2B
03A0 2B2B2B2B2B          .BYTE  X'2B,X'2B,X'2B,X'2B,X'2B,X'2B,X'2B,X'2A
03A5 2B2B2A
03A8 2A2A292928          .BYTE  X'2A,X'2A,X'29,X'29,X'28,X'27,X'27,X'26
03AD 272726
03B0 2524232221          .BYTE  X'25,X'24,X'23,X'22,X'21,X'20,X'1F,X'1D
03B5 201F1D
03B8 1C1B191817          .BYTE  X'1C,X'1B,X'19,X'18,X'17,X'15,X'14,X'13
03BD 151413
03C0 11100F0D0C          .BYTE  X'11,X'10,X'0F,X'0D,X'0C,X'0B,X'09,X'08
03C5 0B0908
03C8 0706050403          .BYTE  X'07,X'06,X'05,X'04,X'03,X'03,X'02,X'01
03CD 030201
03D0 0100000000          .BYTE  X'01,X'00,X'00,X'00,X'00,X'00,X'00,X'00
03D5 000000
03D8 0000010101          .BYTE  X'00,X'00,X'01,X'01,X'01,X'02,X'03,X'04
03DD 020304
03E0 0506070809          .BYTE  X'05,X'06,X'07,X'08,X'09,X'0B,X'0C,X'0D
03E5 0B0C0D
03E8 0F10121315          .BYTE  X'0F,X'10,X'12,X'13,X'15,X'16,X'18,X'1A
03ED 16181A
03F0 1B1D1F2022          .BYTE  X'1B,X'1D,X'1F,X'20,X'22,X'23,X'25,X'27
03F5 232527
03F8 282A2B2C2E          .BYTE  X'28,X'2A,X'2B,X'2C,X'2E,X'2F,X'30,X'31
03FD 2F3031

                         .END
```

Table 5: This table is an encoding of the samples of the waveform used by the program in listing 2. The table is exactly one memory page long on a page boundary. The maximum value of any entry is decimal 63 or hexadecimal 3F to avoid overflow when all four voices are summed.

For example, if more voices are needed, either more modules must be purchased or a multitrack tape recording must be made, which then takes us out of the strict real time domain. On the other hand, a new voice in a direct synthesis system is nothing more than a few bytes added to some tables and a slightly lengthened execution time. Additionally, there may be effects that are simply not possible with currently available analog modules. With a direct synthesis system, one merely codes a new subroutine, assuming that an algorithm to produce the effect is known.

A separate problem for the experimenter is that a "critical mass" exists for serious work with a direct synthesis system. To achieve complexity significantly beyond the 4 voice example program described earlier, a high speed, large capacity mass storage system is needed. This means an IBM type digital tape drive or large hard surface disk drive; usually at least $3000 for a new drive less interface. Used 7 track tapes and 2311 type disks (7.5 megabytes) are often available for $500 and certainly provide a good start if the user can design his own interface. Synthesizer modules or peripheral boards, on the other hand, can be purchased one at a time as needed.

```
*    TOCCATA AND FUGUE IN D-MINOR      BACH
*
VOICE1 40,0,0,0,0,30,0,0,0,0,0,0,0,60,0      10      30,30
VOICE2 37,0,0,0,0,0,0,0,50,0,0,0,0,50,0      10      60,60
VOICE3 0,0,9,0,38,0,0,0,38,19,0,0,0,28,0     15      100,250
TEMPO 1/4=1200

         /-/

002 1A3,1/64; 2A2,1/64
    1A@3,1/64; 2A@2,1/64
    1A3,1/8; 2A2,1/8
    R,1/32
    1G3,1/647; 2G2,1/64.
    1F3,1/64; 2F2,1/64
    1E3,1/64; 2E2,1/64
    1D3,1/64; 2D3,1/64
    1C#3,1/32; 2C#2,1/32
    1D3,1/16; 2D2,1/16
    R,1/4
    3D2,1/1; R,1/4
    2C#3,1F2; R,1/16
    1E3,7/16; R,1/16
    1G3,7/16; R,1/16
    1B@3,5/16; R,1/16
    1C#4,4/16; R,1/16
    1E4,3/16

         /-/

140 1B@4,1/8; 1G4,1/8; 1E4,1/8; 2E3,1/8; 3C#3,1/8
    1E3,1/32
    1G3,1/32
    1B@3,1/32
    1C#4,1/32
    1B@4,1/8
    1B@4,1/8; 1G4,1/8; 1E4,1/8; 1C#4,1/8; 2E3,1/8; 3C#3,1/8
    1A4,1/8; 1F#4,1/8; 1D4,1/8; 2F#3,1/8; 3C3,1/8
TEMPO 1/4=950
    1D3,1/32
TEMPO 1/4=1050
    1A3,1/32
TEMPO 1/4=1150
    1D4,1/32
TEMPO 1/4=1200
    1F#4,1/32
    1A4,1/8
    1A4,3/8; 1F#4,1/8; 1D4,1/8; 2F#3,1/8; 3C3,1/8
141 1D4,1/2; 1B@3,1/2; 2G3,1/2; 3G2,1/4
    1G4,1/2; 3B@2,1/4
    1E4,1/4; 1C#4,1/4; 2B@3,1/4; 3E2,1/4
    1F4,1/4; 1D4,2/4; 2A3,1/4; 3F2,1/4
142 1E4,1/2; 2A3,1/2; 3A2,1/2; R,1/4
    1C4,2/4; R,1/4
    1D4,4/2; 2F3,1/4; 3B@2,1/4
    2B@3,1/4; 2G3,1/4; 3G2,1/4
143 2A3,3/2; 2F3,3/2; 3D3,3/2; 3D2,3/2
END
```

Listing 3: Bach's "Toccata and Fugue in D Minor" as encoded in NOTRAN, a music language developed by the author (NOTRAN stands for NOte TRANslation). The main function of the language is to transcribe organ music, but it will work equally well with other types of music. Program statements are used to encode duration, pitch, attack and decay rates, and loudness of each note.

Music Languages

Ultimately, software for controlling the sound generation process, whether it be direct or real time control, is the real frontier. The very generality of computer music synthesis means that many parameters and other information must be specified in order to produce meaningful music. One function of the software package is to convert "musical units of measure" into physical sound parameters such as conversion of tempo into time durations. Another part is a language for describing music in sufficient detail to realize the control power available from music synthesis without burdening the user with too much irrelevant or repetitious detail. With a good language, a good editor for the language, and real time (or nearly so) execution of the language, the music system becomes a powerful composition tool much as a text editing system aids writers in preparing manuscripts.

Music languages can take on two forms. One is a descriptive form. Music written in a descriptive language is analogous to a conventional score except that it has been coded in machine readable form. All information in the score necessary for proper performance of the piece is transcribed onto the computer score in a form that is meaningful to the user yet acceptable to the computer. Additional information is interspersed for control of tone color, tempo, subtle variations, and other parameters available to the computer synthesist.

A simple example of such a language is NOTRAN (NOte TRANslation) which was developed by the author several years ago for transcribing organ music. Listing 3 shows a portion of Bach's "Toccata and Fugue in D Minor" coded in NOTRAN. The basic thrust of the language was simplicity of instruction (to both the user and the interpreter program), rather than minimization of typing effort.

Briefly, the language consists of statements of one line each which are executed in straight line sequence as the music plays. If the statement starts with a keyword, it is

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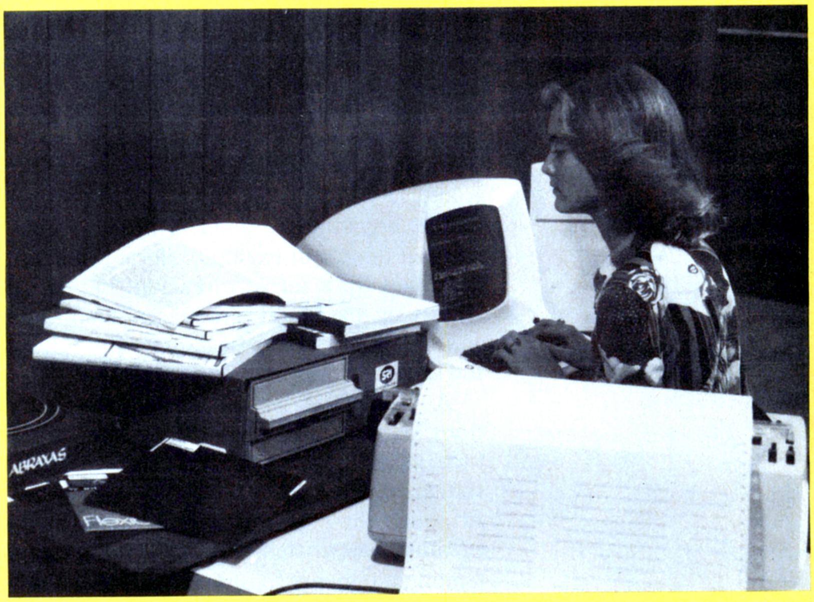

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a specification statement; otherwise, it is a note statement. Specification statements simply set up parameters that influence the execution of succeeding note statements and take no time themselves.

A VOICE statement assigns the timbre described by its parameters to a voice number which is used in the note statements. In the example score, the first group of parameters describe the waveform in terms that are implementation dependent, such as harmonic amplitudes. The next, isolated parameter specifies the overall loudness of the voice in relation to other voices. The last pair of parameters specifies the attack and decay times respectively for notes using this voice. Depending on the particular implementation, other parameters may be added without limit. For example, vibrato might be described by a set of three additional parameters such as vibrato frequency, amplitude, and a delay from the beginning of a note to the start of vibrato.

A TEMPO statement relates note durations in standard fractional terms to real time in milliseconds. The effect of a tempo statement lasts until another is encountered. Although the implementation for which the example was written required a sequence of tempo statements to obtain a retard, there is no reason why an acceleration or a retard set of parameters could not be added.

Note statements consist of one or more note specifications and are indented four spaces (the measure numbers are treated as comments). Each note specification begins with a voice number followed by a note name consisting of a letter, optional sharp (#) or flat (@) sign, and an octave number. Thus C#4 is one half step above middle C. Following the comma separator is a duration fraction. Any fraction is acceptable, but conventional musical fractions are normally used. Following the duration are two optional modifiers. A period (.) indicates a "dotted" note which by convention extends the note's duration by 50%. An "S" specifies a staccato note which is played as just an attack and decay (as specified by the corresponding voice statement) without any steady state. The presence of a semicolon (;) after a note indicates that additional notes which are intended to be part of the same statement are present, possibly extending to succeeding lines.

The execution sequence of note statements can become a little tricky due to the fact that note durations in the statement may not all be equal. The rule is that all notes in the statement start simultaneously. When the shortest one has ended, the notes in the next statement are initiated, even though some in the previous statement may be still sounding. This could continue to any depth such as the case of a whole note in the bass against a series of sixteenth notes in the melody. The actual implementation, of course, limits the maximum number of simultaneous tones that may be built up.

Also available is a rest specification which can be used like a note specification. Its primary function is to provide silent space between note statements, but it may also be used to alter the "shortest note" decision when a note statement is scanned. If the rest is the shortest then the notes in the next statement are started when the rest elapses even though none of the current notes have ended. A use of this property may be seen in the last part of measure 2 where an arpeggio is simulated.

As can be seen, NOTRAN is best suited for describing conventional organ music, although it could be extended to cover a wider area as well. One such extension which has been experimented with but not fully implemented is percussion instruments. First a set of implementation dependent parameters was chosen to define a percussive sound, and then a PRCUS statement similar to the VOICE statement was added to the language. To initiate percussive sounds, specifications such as "P3,1/4" would be interspersed with the note specifications in note statements. The "3" would refer to percussive sound number 3 and the 1/4 would be a "duration" which would be optional. All percussive sounds in the same statement would start simultaneously with the regular notes.

A much more general music language is the well-known MUSIC V. It was designed to make maximum use of the flexibility afforded by direct waveform computation without overburdening the user. It is a massive program written in FORTRAN and clearly oriented toward large computers. Much significant computer music work has been done with MUSIC V, and it is indeed powerful. An excellent book is available which describes the language in detail and includes some background material on digital sound generation (see entry 1 in the list of references at the end of this article).

A different approach to music languages is a "generative" language which describes the *structure* of the music rather than the note by note details. In use, the structure is described by "loops," "subroutines," and "conditional branches" much as an algorithm is described by a computer language. The structure is "executed" to produce detailed statements in a conventional music language which is then played to produce sound. The intermediate step need not necessarily be visible to the user. One well thought out system is described in reference 2. It was actually developed as a musicological analysis tool and so has no provisions for dynamics, timbre, etc. It could, however, be extended to include these factors. One easy way to implement such a language is to write a set of macros using a good minicomputer macroassembler.

Conclusion

By now it should be apparent that computer generated music is a broad, multidisciplinary field. People with a variety of talents can make significant contributions, even on a personal basis. In particular, clever system designers and language designers or implementers have wide open opportunities in this field. Finally, imaginative musicians are needed to realize the potential of the technique.

A Short Cut to a Singing KIM. . .

As his article was being finished by our production department, Hal Chamberlin notified us that he has completed the design of a board which accomplishes the digital to analog conversion and filtering functions described in this article. The board contains printed circuitry for an 8 bit digital to analog converter, low pass filter and power amplifier. Without components, the board may be purchased for $6; completely assembled and tested the price is $35. Orders should be mailed prepaid to Micro Technology Unlimited, 29 Mead St, Manchester NH 03104. In addition, a software package for the KIM-1 computer is available on cassette tape (KIM format) for $13 added to the price of the output board. A 7 inch 16 ohm speaker can be ordered for $5 prepaid, completing the required parts of a KIM's music system. ■

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Are you fascinated with the idea of computerized music, but find the mechanics of producing such effects too complex? I've come up with a simple technique which is the subject of this article, and which is well within the capabilities of the novice computer experimenter. With less than a dozen inexpensive integrated circuits, a few resistors, capacitors and a small prototyping board you can be well on the way to creating interesting music with your Altair, IMSAI or similar computer. My design creates a programmable music tone generator peripheral which has outputs that sound somewhat reminiscent of a clarinet when it is programmed by simple or complex software used to sequence notes in time. The first attempts I made at music generation required complicated programs and many integrated circuits. But as I gained more familiarity with the problem, the project reduced into a relatively simple solution as illustrated here.

The Hardware

The diagram of the melody box hardware is illustrated in figure 1. This hardware is the key to generation of tones from the computer. Software to be described later is responsible for sequencing the notes in time, thus creating a melody. The basic principle of operation of this melody box peripheral is use of a latched binary code in eight bits to select one of several adjustable resistors which will be switched into an oscillator circuit as the timing resistor. In the particular circuit shown in figure 1, I used a pair of 7475 latch circuits to hold the code sent from an 8080's IO instruction; then I decoded the 8 bit pattern with a pair of 7441 circuits which I happened to have on hand in my workshop. The 7441s separately decode two 4 bit codes into selection of one of ten open collector output lines. These output lines are low if the line is selected, and effectively disconnected if not selected. The software used to drive the IO port should be set up to select only one active line by giving out a "null code" such as binary 1111 in one half of the 8 bit word, while selecting a given tone in the other half of the 8 bit word. This guarantees that only one line is in the low state out of a possible 20 lines. The line which is in the low logical state will then affect the frequency of the oscillator implemented by the 555 timer integrated circuit, IC7 of figure 1. The pitch of the note selected is determined by the tuning of the potentiometer associated with a given binary code by the decoders.

The low logic level output of the decoder is similar to a ground or zero voltage. Since all the other lines are effectively floating as open collector outputs, a definite low state on the one line inserts the resistor selected

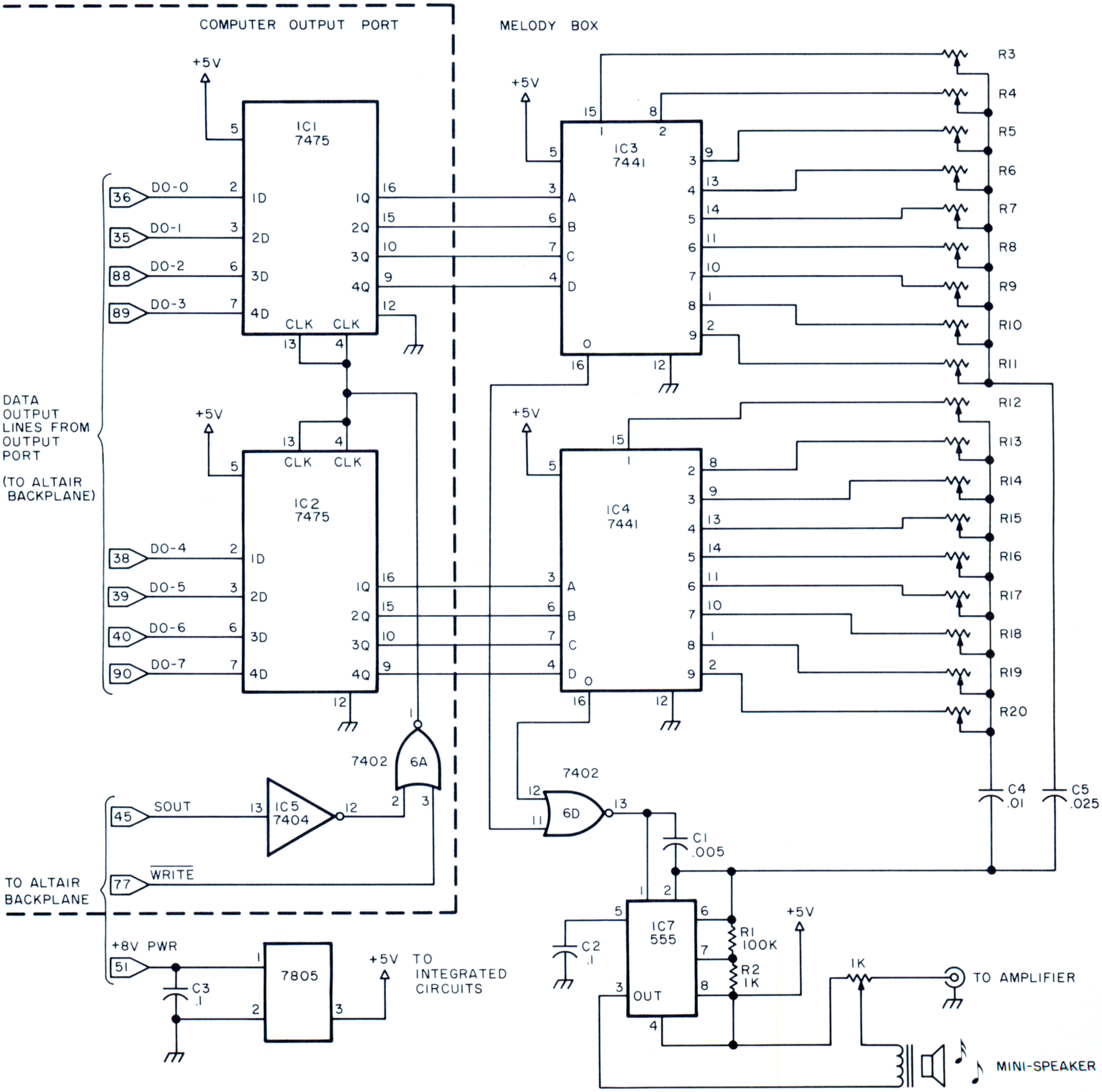
Figure 1: Schematic of the melody box. This circuit works by changing the timing elements of a 555 oscillator integrated circuit to set the pitch. One resistor sets the pitch of each note of the scale. To turn off the oscillator, the circuit detects a special case which turns off the power to the oscillator by raising its ground pin to the high logic level.

⟶

Resistor Number	Potentiometer Value	Approximate Setting
R3	100 k	40 k
R4	100 k	48 k
R5	100 k	56 k
R6	100 k	64 k
R7	100 k	68 k
R8	100 k	76 k
R9	100 k	80 k
R10	100 k	86 k
R11	200 k	90 k
R12	100 k	43 k
R13	100 k	56 k
R14	100 k	67 k
R15	100 k	76 k
R16	100 k	86 k
R17	200 k	95 k
R18	200 k	108 k
R19	200 k	135 k
R20	200 k	152 k

Integrated Circuit Power Wiring

Number	Type	+5 V	GND
IC1	7475	5	12
IC2	7475	5	12
IC3	7441	5	12
IC4	7441	5	12
IC5	7404	14	7
IC6	7402	14	7
IC7	555	8	5


COMPUTER OUTPUT PORT
MELODY BOX
+5V
IC1 7475
IC2 7475
IC3 7441
IC4 7441
IC5 7404
7402 6A
7402 6D
IC7 555
7805
DO-0
DO-1
DO-2
DO-3
DO-4
DO-5
DO-6
DO-7
36
35
88
89
38
39
40
90
1D
2D
3D
4D
1Q
2Q
3Q
4Q
CLK
A
B
C
D
OUT
DATA OUTPUT LINES FROM OUTPUT PORT
(TO ALTAIR BACKPLANE)
SOUT
45
WRITE
77
TO ALTAIR BACKPLANE
+8V PWR
51
C3 .1
+5V TO INTEGRATED CIRCUITS
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
R15
R16
R17
R18
R19
R20
C4 .01
C5 .025
C1 .005
C2 .1
R1 100K
R2 1K
1K
TO AMPLIFIER
MINI-SPEAKER

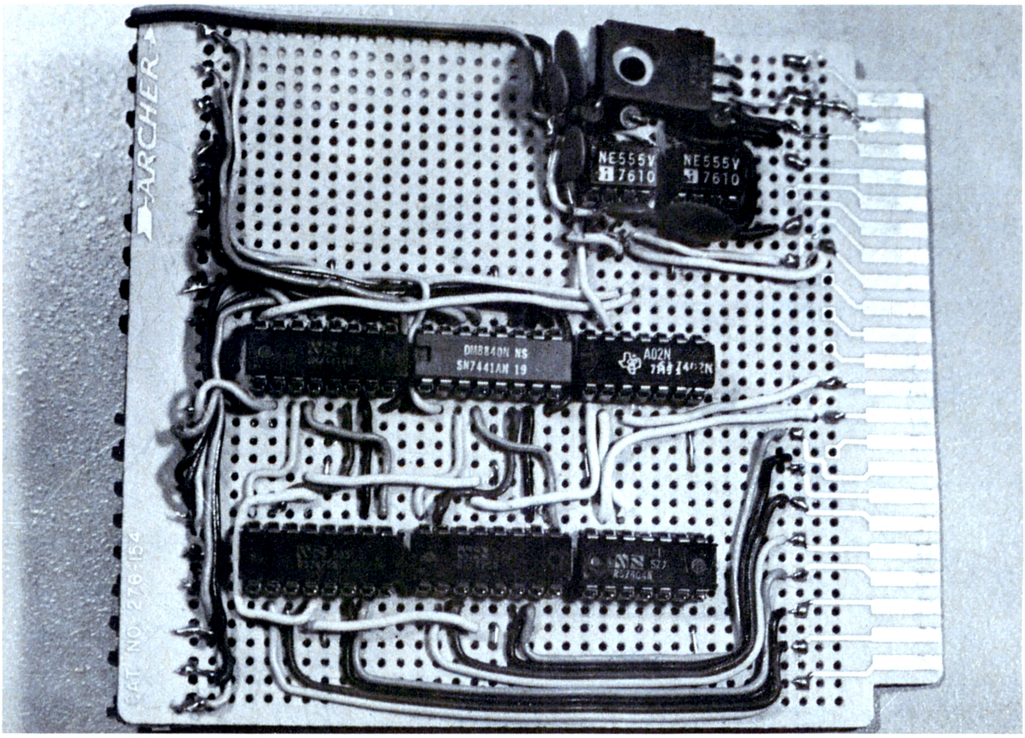


Photo 1: The melody box as constructed, using a Radio Shack prototyping board.

into the 555's timing circuit. The circuit is tuned by running a scale and adjusting the pitches by ear, or even by using a frequency meter.

But what about having no sound at all? Rests are important to music, and there must be some way to turn off the sound. Simply selecting none of the resistors is the first thought which comes to mind, but this does not work very well at all, as you'll find out if you try it. What I did was to put in the NOR gate logic of IC6d to detect when both halves of the 8 bit output word are 0, as indicated by selection of the 0 output line of each decoder. When this happens, the output of the NOR gate is high. Since I use this NOR gate as the power and signal ground of the 555 oscillator, I have effectively removed power from the 555 and turned it off when the double 0 state is output to the port. This may not be optimal engineering, but it certainly works.

My hardware stopped at the point of generating the tones, but for a full range of musical effects, you would certainly want to add some digital controlled filters and amplifiers to this basic pitch generation facility. Some filtration can be accomplished, of course, by manipulation of the tone controls of your high fidelity amplifier.

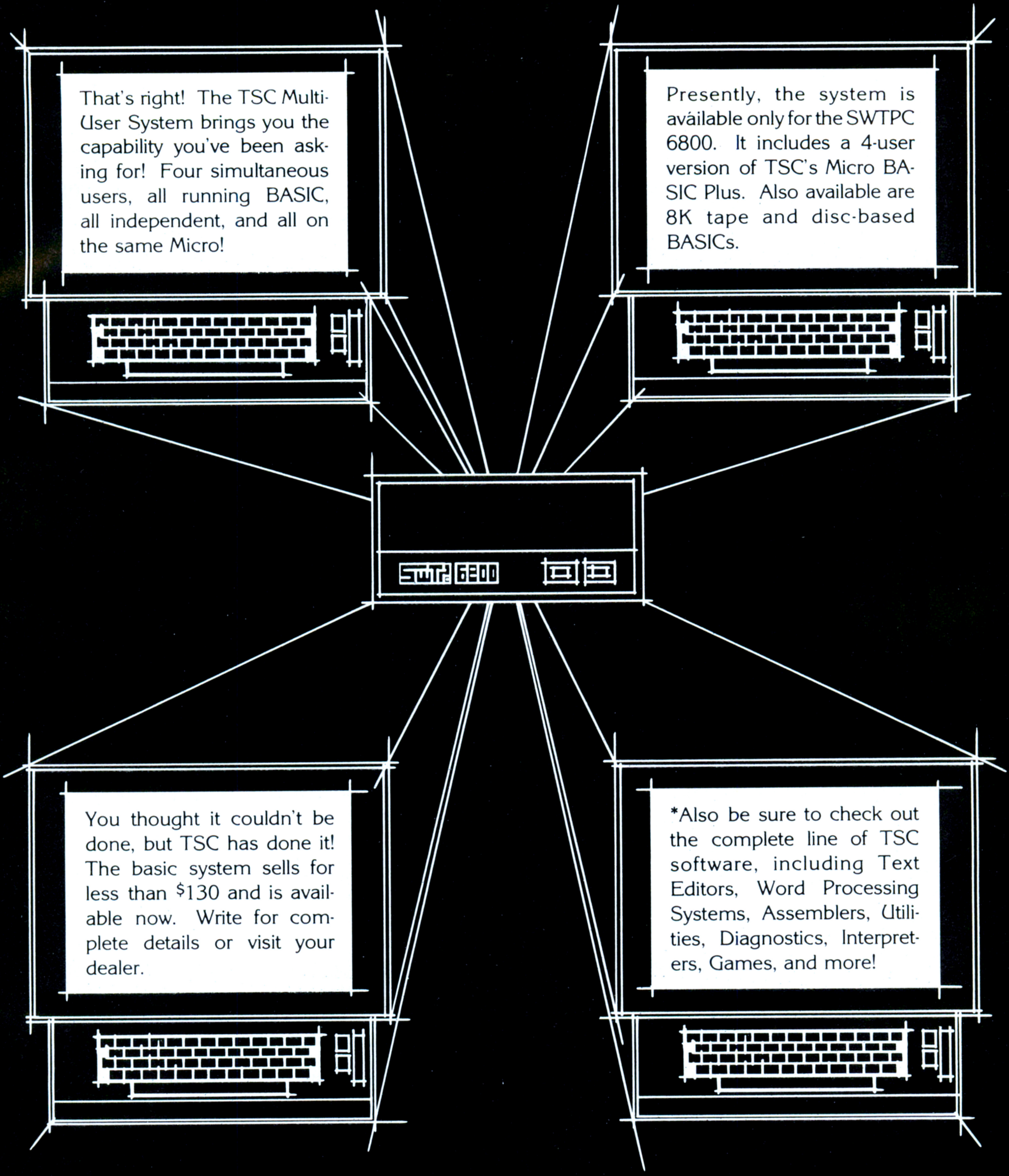
Further Simplifications of Hardware

The circuit of figure 1 is how I built the melody box; but after building it, it occurred to me that several further simplifications could be made. For example, the latches and IO port decoding logic outlined by the dotted lines could easily be replaced by an existing IO port on a computer, such as those provided by the peripheral interface adapters (PIA) of typical IO port boards. The 7441 is not the only open collector decoder chip available, and if you want to make 32 or 64 notes, use of two or four 74159 circuits with a 5 or 6 bit binary code would be possible. The only major disadvantage I find with this circuit is that it has to be tuned individual note by individual note.

Construction

The melody box was built on a Radio Shack IC experimental breadboard, #276-154 (Archer), which plugs into their #276-1551 card connector socket. This type of board has a foil pattern on one side. The integrated circuits or sockets are inserted from the nonfoil side and pins are then soldered to pads designed to take the DIP package pins as well as several connecting wires or components. See photo 1 for a look at my version. I used Molex pins to fabricate sockets for the integrated circuits, although solder tail sockets or no sockets at all could be used depending on your preferences and sources of supply. Wiring is done from the nonfoil side, with stripped ends of the wires going through the board to the appropriate pads. I used multiple colors for the wires in order to make tracing of the circuit easy. The space between the solder

Continued on page 91



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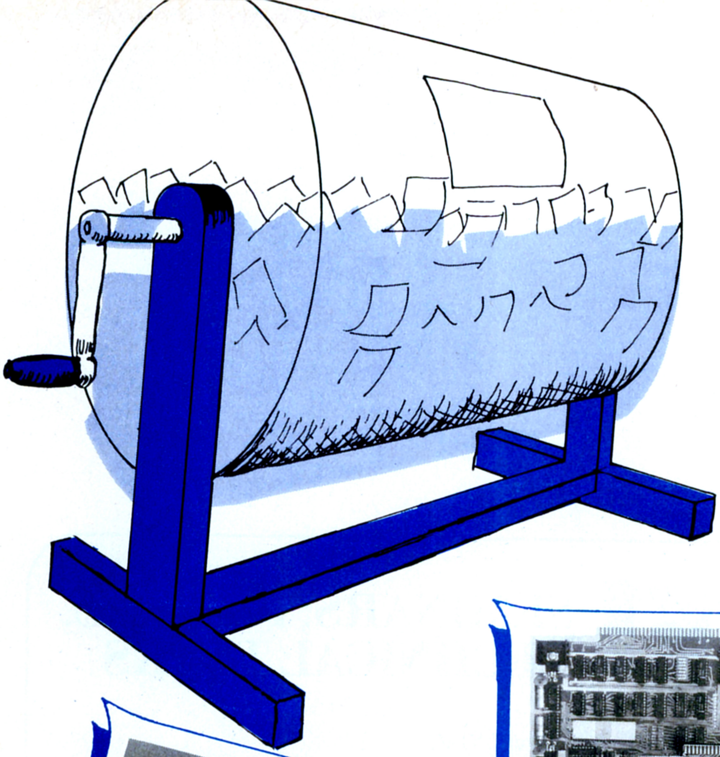

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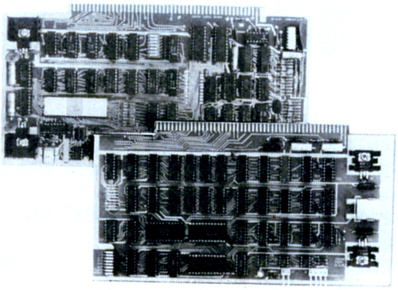

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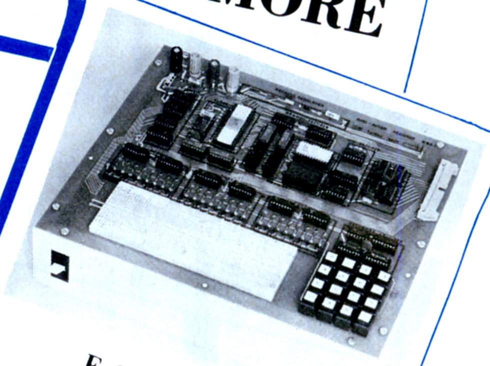

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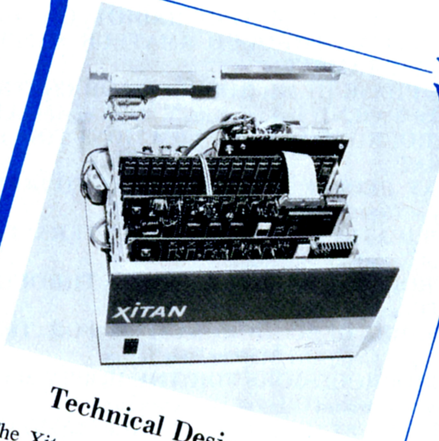

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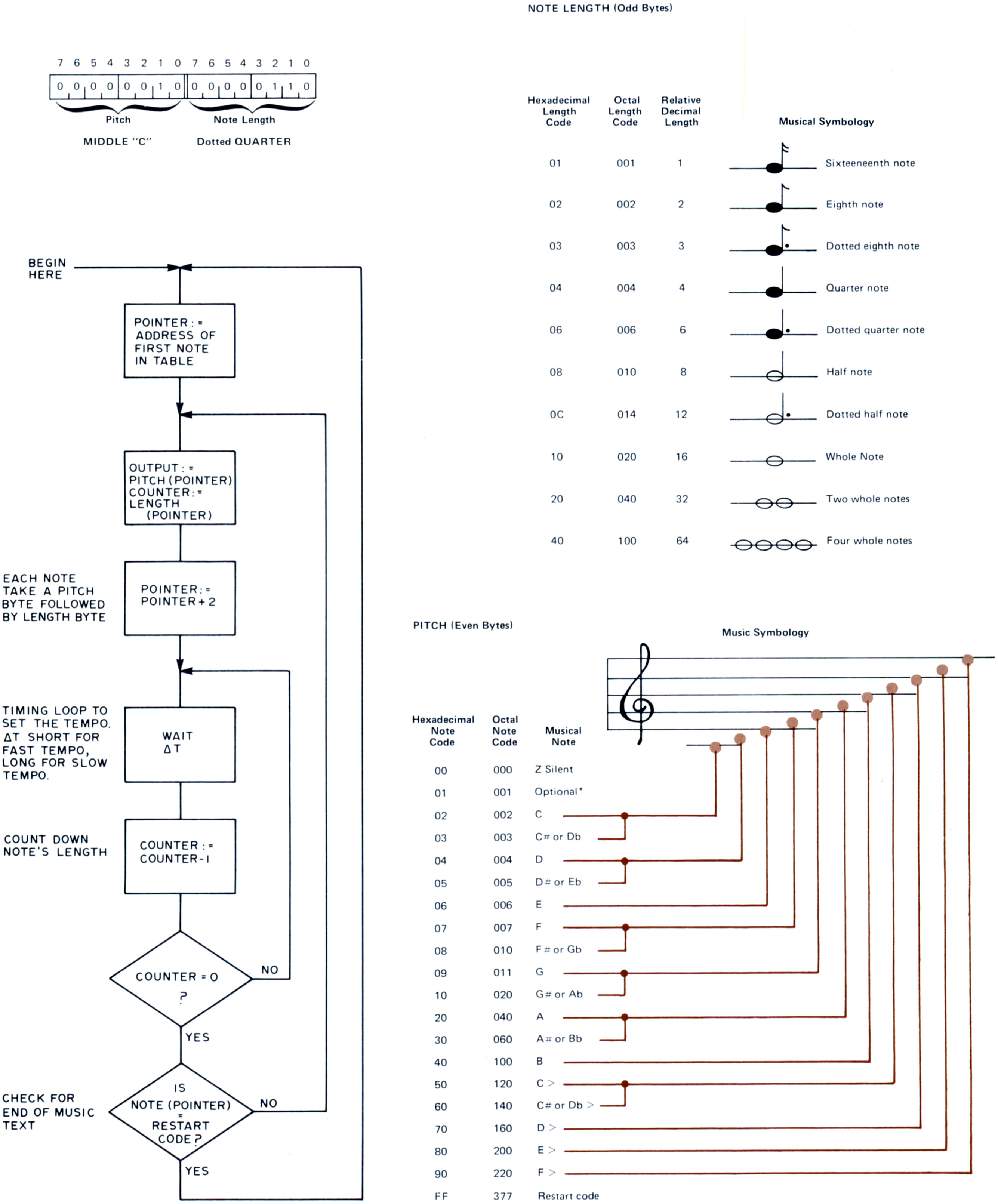
Continued from page 86


7 6 5 4 3 2 1 0 7 6 5 4 3 2 1 0
0 0 0 0 0 0 1 0 0 0 0 0 0 1 1 0
Pitch
Note Length
MIDDLE "C"
Dotted QUARTER
BEGIN HERE
POINTER : = ADDRESS OF FIRST NOTE IN TABLE
OUTPUT : = PITCH (POINTER) COUNTER : = LENGTH (POINTER)
EACH NOTE TAKE A PITCH BYTE FOLLOWED BY LENGTH BYTE
POINTER : = POINTER + 2
TIMING LOOP TO SET THE TEMPO. ΔT SHORT FOR FAST TEMPO, LONG FOR SLOW TEMPO.
WAIT ΔT
COUNT DOWN NOTE'S LENGTH
COUNTER : = COUNTER - 1
COUNTER = 0 ?
NO
YES
CHECK FOR END OF MUSIC TEXT
IS NOTE (POINTER) = RESTART CODE ?
NO
YES
Music Symbology

NOTE LENGTH (Odd Bytes)

Hexadecimal Length Code	Octal Length Code	Relative Decimal Length	Musical Symbology
01	001	1	Sixteeneenth note
02	002	2	Eighth note
03	003	3	Dotted eighth note
04	004	4	Quarter note
06	006	6	Dotted quarter note
08	010	8	Half note
0C	014	12	Dotted half note
10	020	16	Whole Note
20	040	32	Two whole notes
40	100	64	Four whole notes

PITCH (Even Bytes)

Hexadecimal Note Code	Octal Note Code	Musical Note
00	000	Z Silent
01	001	Optional*
02	002	C
03	003	C# or Db
04	004	D
05	005	D# or Eb
06	006	E
07	007	F
08	010	F# or Gb
09	011	G
10	020	G# or Ab
20	040	A
30	060	A# or Bb
40	100	B
50	120	C >
60	140	C# or Db >
70	160	D >
80	200	E >
90	220	F >
FF	377	Restart code

Figure 2: Programming model for the melody box. The note pitch and length codes listed are interpreted by the program shown as a flowchart here. Each note is completely specified by a pitch code and a length code contained in two bytes of memory as shown by the example.

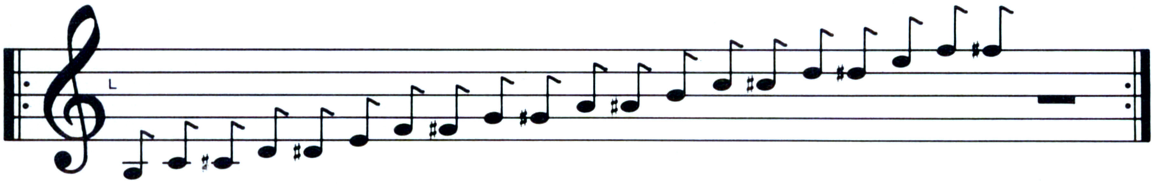


Figure 3: The melody box notes are tuned by running this chromatic scale text through the program of figure 2. While listening to the scale, adjust each note's potentiometer until the sound is a correct musical interval.

A Set of Chromatic Scale Data for Tuning the Melody Box

Octal		Hexadecimal		
Relative Address	**Note and Length Code**	**Relative Address**	**Note and Length Code**	
000	001 002	00	01 02	
002	002 002	02	02 02	
004	003 002	04	03 02	
006	004 002	06	04 02	
010	005 002	08	05 02	
012	006 002	0A	06 02	
014	007 002	0C	07 02	
016	010 002	0E	08 02	
020	011 002	10	09 02	
022	020 002	12	10 02	
024	040 002	14	20 02	
026	060 002	16	30 02	
030	100 002	18	40 02	
032	120 002	1A	50 02	
034	140 002	1C	60 02	
036	160 002	1E	70 02	
040	200 002	20	80 02	
042	220 002	22	90 02	
044	000 040	24	00 40	
046	377 xxx	26	FF xx	repeat code

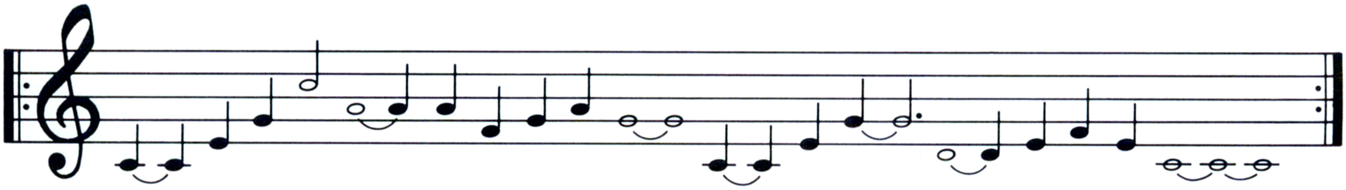


TABLE LOCATIONS→
OCTAL 000 002 004 006 010 012 —— 014 016 020 022 024 —— 026 030 032 034 036 040 —— 042 044 046 050 ——
HEXADECIMAL 00 02 04 06 08 0A —— 0C 0E 10 12 14 —— 16 18 1A 1C 1E 20 —— 22 24 26 30 ——

Figure 4: A test string, shown in machine code form and in traditional musical representation, sans time signature, using note lengths as defined in figure 2.

A Familiar Tune

Octal		Hexadecimal		
Relative Address	**Note and Length Code**	**Relative Address**	**Note and Length Code**	
000	002 004	00	02 04	
002	002 004	02	02 04	
004	006 004	04	06 04	
006	011 004	06	09 04	
010	120 014	08	50 0C	
012	040 024	0A	20 14	
014	040 004	0C	20 04	
016	007 004	0E	07 04	
020	011 004	10	09 04	
022	040 004	12	20 04	
024	011 040	14	09 20	
026	002 004	16	02 04	
030	002 004	18	02 04	
032	006 004	1A	06 04	
034	011 004	1C	09 04	
036	011 014	1E	09 0C	
040	004 024	20	04 14	
042	006 004	22	06 04	
044	007 004	24	07 04	
046	006 004	26	06 04	
050	004 004	28	04 04	
052	002 030	2A	02 18	
054	000 001	2C	00 01	
056	377 xxx	2E	FF xx	stop

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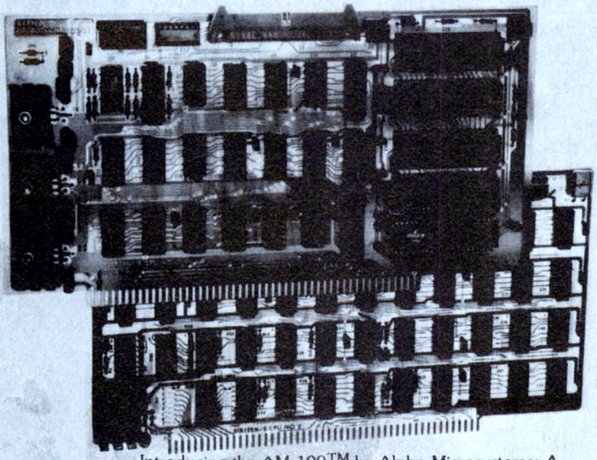

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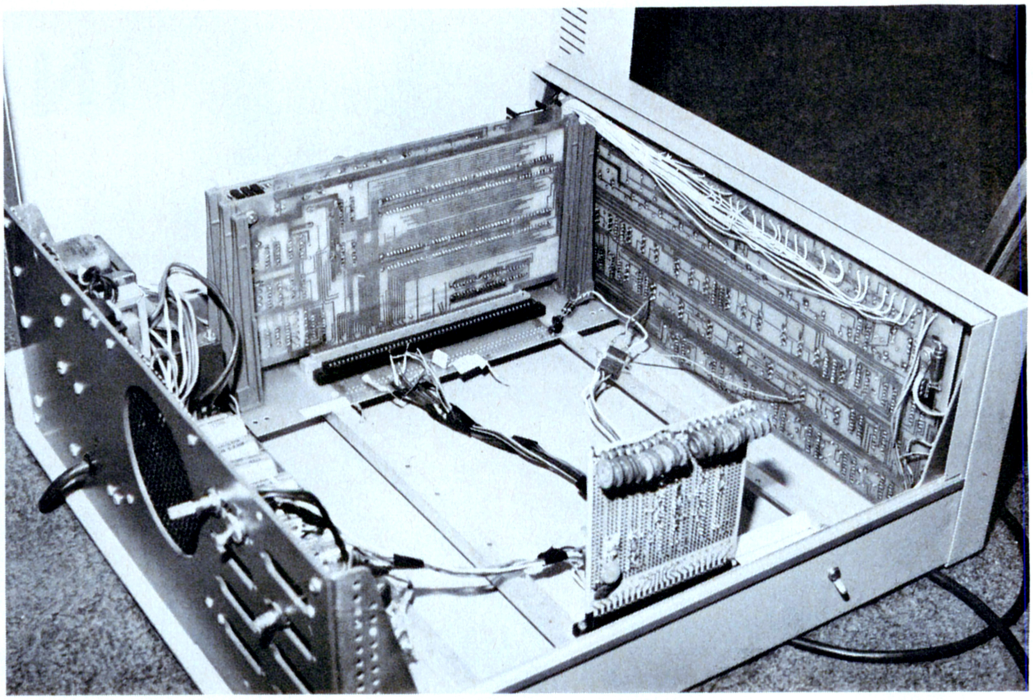


Photo 2: Installation of the melody box inside an Altair 8800 is accomplished by wiring various wires from the backplane of the computer. The power switch and volume control were mounted on the back panel of the computer, so that the melody box could be turned off.

pads and bus lines of the card is relatively small, so care must be used to prevent solder bridges from forming. I recommend a low wattage iron with a pencil tip. 25 to 30 W will work well.

The 20 variable resistors used can typically be found at prices from $.20 to $.49 depending on how good you are at shopping around. I mounted the actual melody box inside my Altair 8800, as shown in photo 2. The circuit connections to the Altair bus were made as shown in figure 1. When mounting the circuit inside the computer cabinet, care should be taken to prevent damage to existing boards of the computer. I found that covering the boards with a layer of paper was a good precautionary measure to prevent any splatter of solder. In order to make the Altair connections, you must remove the mainframe backplane board (the one with all the edge connectors) so that you can solder to the underside.

Software for the Melody Box

The melody box requires instructions to tell it what to do. In an organ, piano or other instrument, a special purpose keyboard gives instructions about what note to play and for how long. Making the melody box play a tune consists of writing a program to generate a time sequence of instructions.

A programming model for the melody box is summarized in figure 2. The data required for each note is the pitch of the note, and the length of the note. In the program I wrote for my Altair, I used one 8 bit byte to represent the pitch, followed by a second 8 bit byte with an integer count giving the length. A table of the pitch codes, referenced to a music stave, and a table of length codes with equivalent note symbols are shown as part of figure 2. The flowchart in figure 2 shows an algorithm which is easy to implement on any small computer. In my own system, I enter these codes with the front panel toggle switches and the "deposit" function.

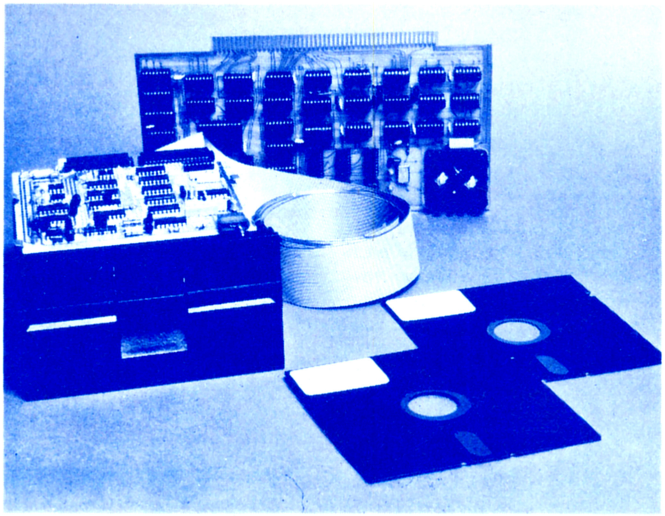
Once you have coded up the details of a program which will execute the flowchart of figure 2, the first step is to tune the melody box. In figure 3 I've shown the musical representation of an ascending chromatic scale, as well as the corresponding table of byte values (in octal and hexadecimal) for the 2 byte note pitch and length codes required to play this scale. An arbitrarily long rest follows the end of data before the repeat. Tuning is accomplished by ear (assuming you know what a scale sounds like) while playing this chromatic scale with the program. The potentiometers of the circuit in figure 1 should be adjusted until the scale sounds "right."

As a second example, figure 4 shows a familiar tune, both in music notation and as a table of values for the music program to utilize. In the music notation, the table locations are written below in hexadecimal and octal to show how the two representations correspond. The limits on what tunes you can play are only dependent upon how much imagination you have and how big your Altair's memory is.■

Continued from page 6

nating or experienced user, the wealth of options available in the many varieties and permutations of 8080, Z-80, 6502, 6800 and 9900 systems at reasonable prices make it less and less likely that our readers will continue to be frustrated and annoyed by such devices of torture as job control, account numbers, contention for the use of a system, and the host of limitations encountered when commercial and industrial systems are twisted to personal purposes in "off" hours.

During the coming year, our third as a magazine born out of and devoted entirely to personal computing, we expect to see continued evolution in the field. The last half of 1977 represents the entry of several relatively large concerns into the marketplace, in the form of Heathkit this summer and Commodore soon to follow. Rumors have it that companies ranging from Atari and Bally Manufacturing (arcade games) to Radio Shack and Texas Instruments are in the process of developing general purpose systems appropriate for personal computing uses. This sort of "confirmation" of the marketplace's existence is bound to keep all firms on their competitive toes and ultimately benefit the user who is presented with more options and ways of achieving the personal computing function. (We even see the same phenomenon in our own subbranch of the industry, the publications devoted to personal computing.) Like all industries, we can expect to see ups and downs in the trend, but for the moment we certainly relish and enjoy the heady expansion and growth evident all around us. Once again, technology in its application to human affairs is having its effect, and our lives as individuals are being improved as a result, despite the pessimists, gainsayers and prophets of doom chattering on about their usual maudlin spectres. We have yet to see large and useful personal data banks, practical automatons and similar challenges which have been projected by the writers of "hard" science fiction. But even if such are seen in our lifetimes, one thing is certain: the challenge of technology and invention which so marks the human race will continue with new horizons, just as today's computer technology could scarcely have been envisioned 20 years ago.■



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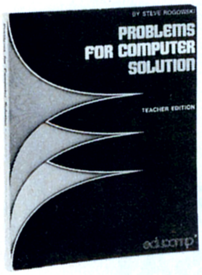

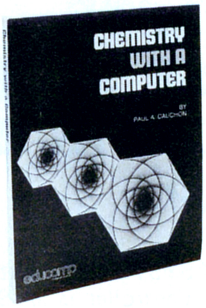

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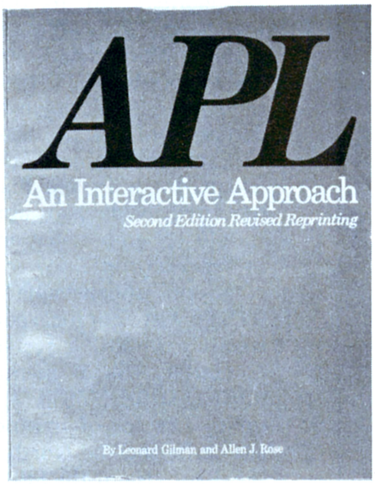
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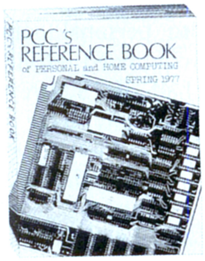

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A NEW CHESS SPECIAL INTEREST GROUP

Recently three computer chess programs have become available to the computer hobbyist, and two dedicated chess playing machines have been announced. The newspapers carry news of the US and international computer chess tournaments.

With this growing interest, one would expect that there'd be some medium of communication among devotees of computer chess. But the only articles appear in obscure professional publications which the average reader never heard of. So, having tried to get someone else to do it, I decided to try to start a *Computer Chess Newsletter*, with the contents furnished by the readers, based upon a model provided by Hal Singer's pioneering *Micro-8 Newsletter* for computer users. Now the problem is to get contributions. Anyone with any interest in computer chess playing or programming, please write. So far no price, size, or frequency of publication has been determined.

We need letters and articles about experiences with specific programs, either on hobby machines or the larger programs available on some campus computers and some timesharing systems. In fact, we need a list of known programs. How do they compare, for strength, for speed of response, for the way the moves are reported, the way the board is displayed?

Lots of hobbyists would like to try their hand at writing a chess program but don't know how to get started. Any advice or experience in this would be most appreciated. Also, descriptions of chess programs and their philosophies would be most welcome. There is not exactly a surplus of material to read on things like this.

Anyone interested in receiving the first issue should send a letter enclosing a couple of 13¢ stamps to defray costs for the first try. I hope that a great deal of interest shows up in the form of contributions of material for the newsletter.

Doug Penrod
1445 La Cima Rd
Santa Barbara CA 93101

For an interesting news item on the subject of computer chess, readers should consult the June 1977 Scientific American, *the "Science and the Citizen" column, page 56. This report covers the first computer program to answer chess master David Levy's 1968 challenge (which is up in 1978). The program was Chess 4.5, a product of Lawrence R Atkin and David J Slate of the computation center at Northwestern University. In ordinary tournament play, the chess program lost; in "blitz" high speed play, the program won handily. The details and play-by-play account of the game are in the* Scientific American *piece.* ■

Ask BYTE

INTERACTIVE COMMENTARY — APL ROMs CONTINUED

I have thoroughly enjoyed your magazine for some time now; even though I can't really be termed a "home hacker" (I run on a PDP-11/45 under RSTS or UNIX), it is still interesting and very informative. Keep up the good work!

I would like to comment on a few letters from recent issues. First, on the APL character set ROMs: I would love to see this developed, and made available soon and relatively inexpensively. APL is a wonderful language, but is not widely enough available to be well known. I have worked on an APL interpreter for our 11, which is compatible with APL/360; however, we don't have enough APL terminals, so I thought of getting some ROMs burned for DECwriters, but it turned out to be too

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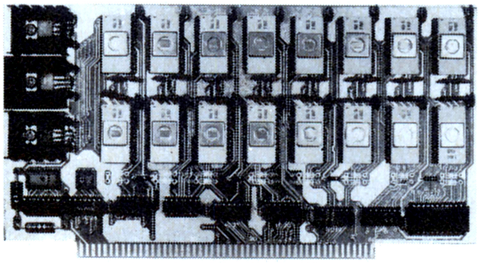

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expensive. If some other people want to get together and get them done, count me in! Also, if anyone out there is working on a "tiny APL" for an 8080 or another microprocessor, contact me; I'd like to hear what you're doing. I've given it some thought myself, but don't have a microprocessor handy to play with.

Second, to P M Lashley in February 1977 BYTE, I must say that while FORTRAN may be a "virtual pterodactyl," it does have its merits, the biggest one being portability. I program in "C" mainly, a beautiful language, impeccably cleanly structured; but how many of you out there have heard of it, much less know where you could run it? This is the one point in which FORTRAN outweighs its competitors; however, much better they may be. If this is of no concern, be my guest and scrap FORTRAN! (I'll help!!)

Thanks for a fine mag. I'm sure I won't be disappointed in the years to come.

Christopher A Kent
935 Burney Ln
Cincinnati OH 45230

Having recently conversed with a representative of a firm planning an APL "black box" computer, we found that according to the gentleman in question a full APL interpreter does not have to be an emulation of a 360 with several hundred thousands bytes (as is the case in IBM's 5100 APL). This caller claimed it was possible to implement APL for an 8080 or Z-80 in under 12 K bytes with clever programming. See Mike Wimble's articles for the algorithms.■

MORE BASIC QUESTIONS

In your March 1977 BYTE, you listed a Space War game in BASIC written by David Price (page 106). In his game he uses the instruction MAT. I have just purchased an SwTPC 6800 12 K byte computer with SwTPC's 8 K BASIC. SwTPC's BASIC does not have a MAT instruction. My question is: What can I use to substitute in place of the MAT instruction?

Steve Wright
13900 SE Highway 212, SP#74
Clackamas OR 97015

The MAT refers to "matrix" operations. In David Price's program, the concept of a matrix (often a two-dimensional one) is used to represent a two-dimensional array of values. For example, line 520:

```
MAT K=ZER(3,3)
```

The "MAT" at the beginning of a line is your cue that an array or "matrix" is involved. In the statement above, this would be equivalent to writing:

```
DIM K (3,3)
FOR I=1 TO 3
FOR J=1 TO 3
K (I,J)=0
NEXT J
NEXT I
```

(The DIM is only needed once in a program, at or near its beginning.) In David's program, the MAT statements are essentially used only to allocate storage for matrix data type arrays, followed by initialization similar to the example shown. There are other operations applicable to matrix data, but most uses of the matrices in David's programs refer to components, once values have been initialized. If you do not have a two-dimensional array facility, a much more difficult simulation of two-dimensions is also possible.■

SOME BASIC VARIATIONS

I put the March 1977 BYTE "Star Trek" program (page 106) on disk in an IBM VM 370 operating system with a timeshared terminal. I encountered several problems due to the differences between VM 370 BASIC and the version used by David Price in his program. Most were solvable with the help of a guide at the end of the article, but a few still have me stumped.

Continued on page 209

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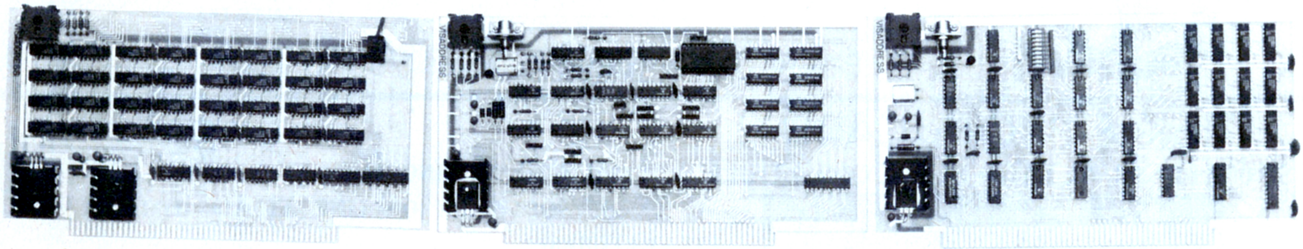

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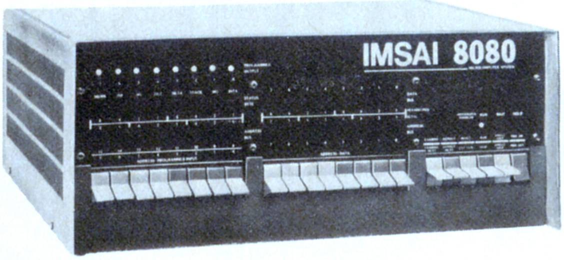

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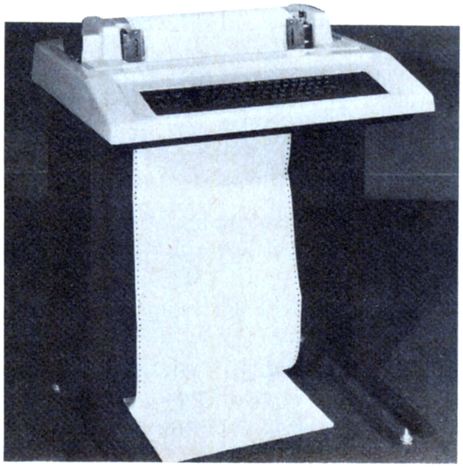

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System Description: The Noval 760

Here is the designer's eye view of a new product which represents one of the most complete ready to run computer packages seen to date. Introduced with a 4 page advertisement in June 1977 BYTE, this manufacturer's product description provides some more detailed information for readers' inspection and evaluation.

Lane T Hauck, Director of Research and Development
James D Nash, Senior Systems Programmer
Noval Inc
8401 Aero Dr
San Diego CA 92123

The first wave of personal computing hysteria seems to have subsided. A casual stroll through the West Coast Computer Faire last spring served as a pretty clear indication that the small computer user has grown up in a big hurry. We now hear these alleged "kids" rapping about relocatability, graphics generation and memory design, a far cry from the "dumb" user concept.

The Noval 760 computer was designed to fill the needs of the advanced hobbyist, who has a serious interest in learning about writing and using software. The system emphasis at Noval has been placed on provision of a unified hardware and software package which facilitates program development. The Noval 760 system does *not* allow the user to pick up a 4 year degree in computer science within two weeks by following the manual, but it does simplify some of the "dog" work required to design, write and debug programs written for amusement or more serious business.

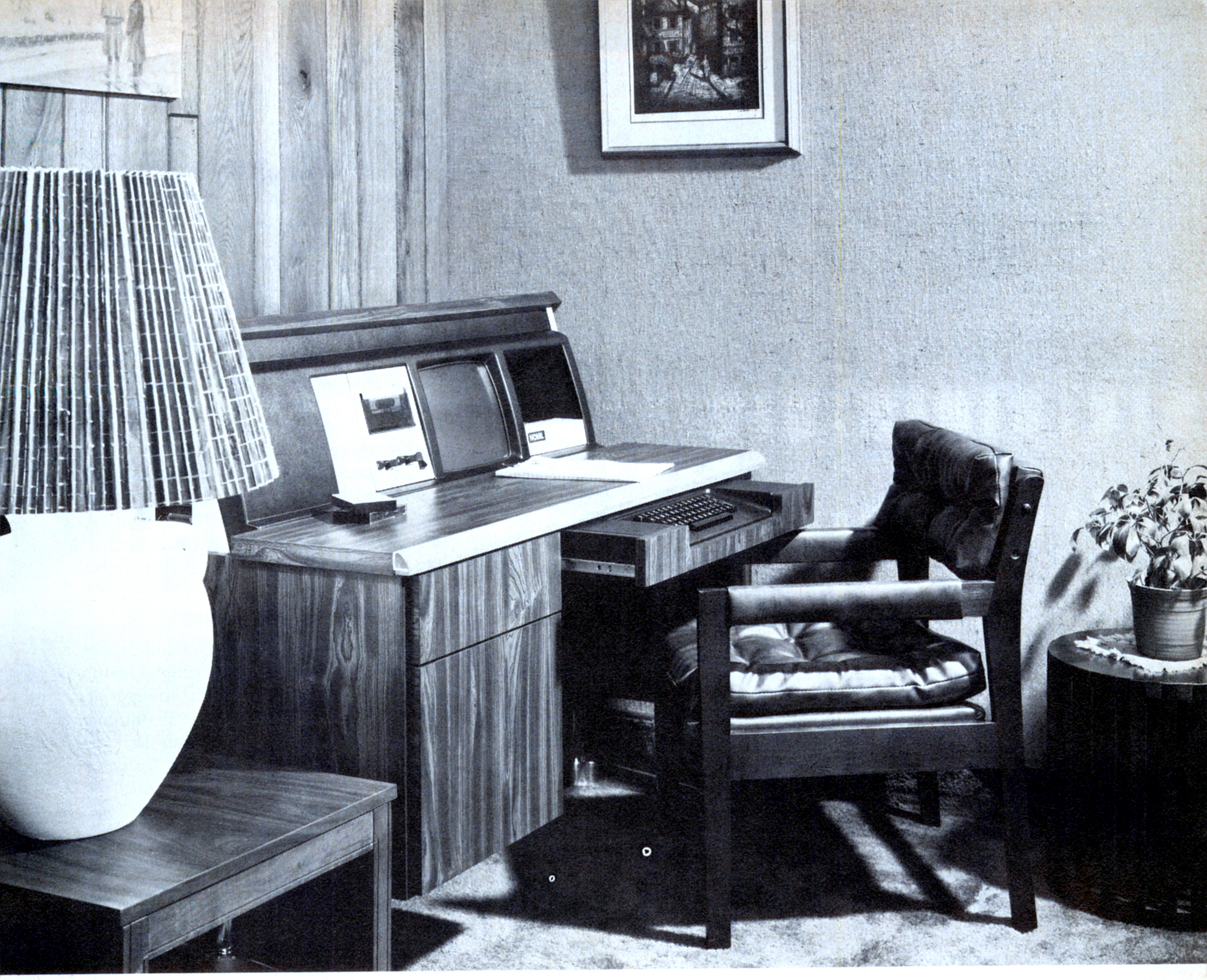
The most startling aspect of the 760 is its package. The computer system is housed in an attractive desk, which in its "folded" position is a piece of contemporary furniture. It is, in fact, fully functional as a desk, complete with drawer space. However, lifting the rear half of the desk top (photo 1) reveals a computer console with video display and cassette mass storage. The center drawer pulls out to reveal a full alphanumeric keyboard.

The design philosophy of the 760 system is to provide a fully assembled and tested computer, with everything needed to develop and run programs. This philosophy is carried through all aspects of the hardware and software, and especially in the way the hardware and software work together.

Hardware

The Noval 760 computer is based on an 8080A microprocessor. The standard hardware includes:

- 16 K bytes of user program memory.
- 3 K bytes of PROM systems software.
- 12 inch (30 cm) solid state monitor.
- Full alphanumeric keyboard.
- 32 column printer.
- Digital cassette tape unit with full electronic control.
- Eight built-in IO ports (three user available).
- Heavy-duty power supply.
- Graphics system, including 1 K bytes of user programmable refresh memory, 2 K bytes of user programmable char-



acter generator memory, and 1 K bytes of scratch pad memory.

Dynamic memories with invisible refresh are used for all programmable memory. No memory wait states are generated, and full refresh is maintained when the system is halted. An optional second memory board expands the system to 32 K, and PROM expansion to 16 K is optional.

The standard software PROM occupies 3 K bytes, with sockets for an additional 1 K bytes of user supplied PROM. The system uses a direct video monitor for a clear, crisp display. The wide bandwidth attained using the direct drive approach is especially important in the high resolution graphics mode.

The drawer mounted keyboard has all the standard ASCII keys, plus special control keys for video games, such as up and down arrows. The keyboard is scanned and encoded using software, so that key codes may be arbitrarily assigned, if desired.

The printer is a dot matrix impact printer, manufacturered by LRC Products Inc. Rather than employing a standard ROM for character generation, the software creates the images to be printed. This allows user defined symbols to be created along with standard ASCII characters, a graphics mode which enhances the usefulness of the printer as a plotting device.

The tape mass storage unit is a PhiDeck, with Noval designed electronics, capable of reading and writing at 2500 bits per second. This allows a 4 K byte program to be loaded or saved in about 20 seconds.

The IO system is implemented using a distributed logic technique. One corner of the main printed circuit board is devoted to eight parallel connected Molex connectors of 20 pins each. All signals from the processor which are necessary to implement the first eight ports (ports 0 to 7) are bussed to these

Photo 1: The Noval 760 is shown in this picture as it appears in its natural setting for use: unfolded in a living room, office or den. The console with display and cassette drive folds into the desk and the drawer with its keyboard closes, so that when not in use the Noval 760 blends into the decor as a desk-like woodtone piece of furniture.

connectors. The cable for any peripheral is terminated by a small printed circuit board which contains four integrated circuits which actually implement the IO port.

The graphics system is one of the nicest aspects of the Noval hardware. The display system contains its own 4 K byte volatile memory which is dedicated to image generation and display. Control of the screen is done using a memory mapped approach, so that every screen location has a unique memory address. This allows fast access to any screen location using any of the 8080A memory referencing instructions.

The graphics system is character oriented with user defined character graphics. 1 K bytes of the video memory are devoted to holding the character codes for the screen which are accessed every time the beam scans the CRT. The screen is organized as 28 rows of 32 characters each. The character codes span a full 8 bit range which gives the capability for defining 256 different characters. The characters are formatted as an 8 by 8 array of "dots." The definition of these dot patterns is contained in a second 2 K byte image memory, also user programmable. (A little figuring shows that to represent 256 different images of 64 dots each requires 2 K bytes of memory.) Since, like the refresh memory, the image memory is treated like any other 8080A system memory, it can be directly accessed using conventional memory reference instructions. "Loading" the character generator is simply a matter of writing bit patterns (which will be displayed as dot pattern on the CRT) into consecutive memory locations.

What about color? This feature is built into the system, but an external color monitor is required to use it. The system allows the user to define four different color "schemes" for use with such a monitor, where each scheme consists of eight pairs of image and background colors. Although the color schemes themselves require burning a 32 by 8 PROM, selection of one of the four is done in software.

1 K bytes of memory physically located in the video system are available for general purpose use. In all Noval system software, the 8080A "overhead" variables such as the stack data and system flags are stored here, so that the user has maximum use of the 16 K byte (or 32 K with expansion) memory elsewhere in the system.

The development of hardware for the Noval system was closely paralleled by intensive software development. It is the "cooperation" between these two disciplines which we feel has produced a successful integrated package.

Software

Noval software is organized around a number of utility and supervisory routines which are collectively referred to as the system "monitor." In the minimum system configuration, a 3 K byte PROM resident segment of the monitor contains a command processor, a few utility routines and the software required to communicate with the front panel, keyboard, CRT and cassette tape. The primary function of this 3 K program is to load other monitor and system routines from cassette (unless a PROM option has preloaded this data).

Standard software includes an editor, assembler, debugger, and a graphics character generation package. As an option, all of the above software can also be installed in PROM. A BASIC interpreter is also available.

Editor, Assembler and Debugger

The Noval editor, assembler and debugger for 8080A code have many unique features. Before examining this system, however, let's quickly outline what these development tools are traditionally designed to do.

An editor allows you to enter, format and modify ASCII text. Input to the editor is either old text which is to be modified or new lines of text which are typed in. Text output from the editor is used as input to the assembler. The assembler input is called a source program. The assembler translates the "source" into binary codes which are intelligible to your processor. Traditionally on large machines and many minicomputers editors and assemblers are independent programs; text created by the editor must be saved somewhere while the assembler is being loaded. When the assembler has been loaded, the edited source program can be reloaded and assembled.

When assembly is complete, the assembler produces a listing of the source program and the associated binary codes. The binary codes are called the object program. The assembler output also includes a list of errors found in the source program. Perhaps you typed MOB A,B instead of MOV A,B, or maybe you forgot to define label "LOOP." So back you go to the editor. Load, reedit, save, load, reassemble, . . .

The Noval system uses an interactive approach to editor and assembler design. The Noval editor can be used in a mode which checks each line of proposed assembly language code for syntax errors as it is entered. Thus when you type "MOB A,B" and attempt to insert it into the text, the editor does not allow the line to be inserted. Instead, an error message is issued and the

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line must be retyped. The method used involves the editor and assembler working together; the assembler is called by the editor to check the syntax of each proposed instruction. The editor cannot check for every possible assembly error condition, but errors that are caught constitute a large percentage of typical assembly errors. The editor's interactive assembly mechanisms can, of course, be disabled to allow input of arbitrary text as well.

The mechanics of using the editor and assembler have been kept as simple as possible. A 2 letter keyboard command (ED) calls the editor from the monitor's command processor. The first 24 lines of text (if any) are displayed immediately. Each line of text has been automatically assigned a line number. One letter keyboard commands allow you to insert (I), erase (E) or change (C) lines. Up arrow (↑) and down arrow (↓) allow viewing of previous or upcoming pages of text. Any specific section of text can be displayed by simply typing the line number. A search command (S) allows capability to search for any ASCII string. All editor commands immediately display the results of command execution. An inserted line, for example, is immediately displayed along with its neighboring lines.

The "ESC" key causes exit from the editor and returns control to the monitor command processor. All assembler commands work directly on prescanned text created by the editor, with no need to save intermediate results. Assembler options include capabilities to assemble and list errors, assemble and print assembly listing on the printer, assemble and display a listing on the CRT, and execute the object program after assembly. When assembly errors are noted (most are undefined labels since syntax is checked during editing), the editor can be immediately recalled and the source program modified. The Noval editor and assembler interaction helps minimize the time spent in the program development cycle, a concern which is just as important to the amateur as it is to the professional programmer.

The monitor save text command allows saving any number of lines on the cassette tape. Special assembly commands allow segments of the large source program to be read into memory, assembled and linked to previously assembled segments. Very large programs can be assembled in this manner. The ultimate size limitation essentially depends only on the amount of available memory.

When the source program has assembled properly, typing OD transfers control to the Noval ODT (On-line Debug Technique) command processor. From here insertion of software breakpoints and use of the ODT jump command allow the user to execute any segment of object program. Before the jump all 8080A registers can be preset. Upon hitting a breakpoint (a dedicated restart instruction, "RST 2"), the breakpoint address is displayed along with all register values, the stack pointer address and previous elements on the stack. When the entire development procedure is complete, the debugged source and object programs can easily be saved on cassette tape.

Leave the Driving to Us

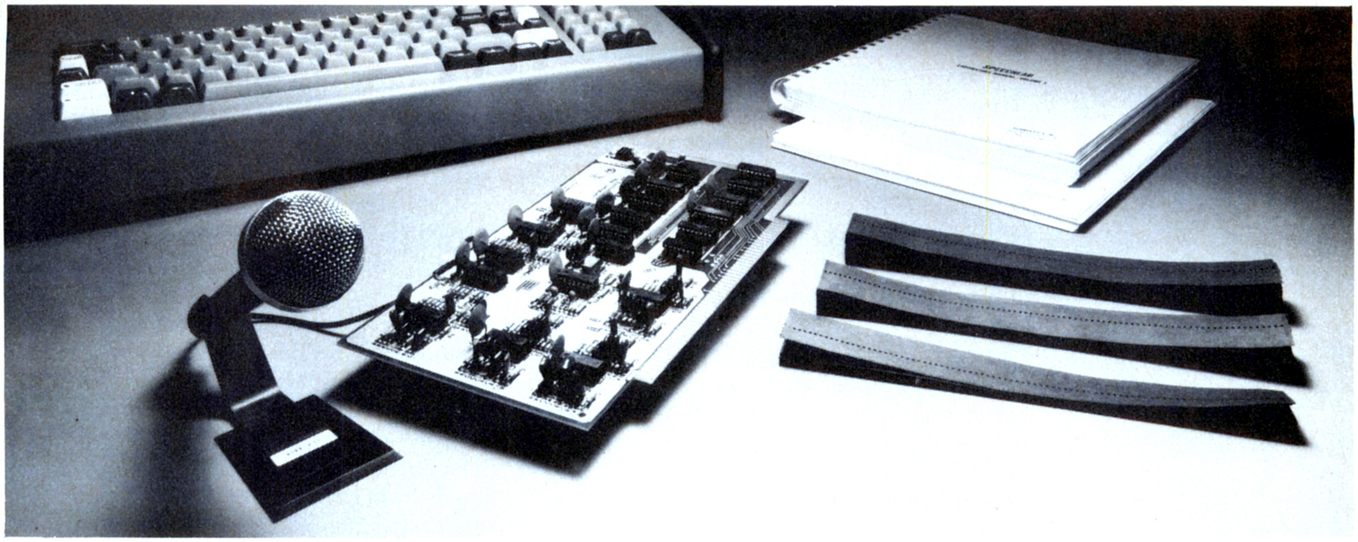
Communication between the central processor and peripheral equipment in this (or any) system is accomplished with software "drivers." Drivers deal with the detailed workings of system input or output, and, at best, are organized to make such communication an easy task. Drivers for all peripherals in the Noval system are included in the standard PROM monitor. Also included is extensive documentation on how to use each of them. Furthermore, the monitor includes a large number of utility routines which can be used for special purpose programming applications. Examples include a routine to print ASCII text on the screen; routines to create and display graphics characters; a routine to find a keyboard key "push" and return the ASCII code for the key. In total, the user of the Noval system has access to over 75 systems routines which can be used in a variety of applications.

An Eye Toward Revision

One problem with accessing drivers using subroutine calls is that absolute address of the subroutine must be known. As subroutine revisions are made, absolute addresses change and all references to subroutines must be modified. Typically, a reassembly of a large amount of user applications software is required each time system subroutines are modified. *[Perish the thought.]* Noval monitor utility routines can be called without knowing the absolute address of the routine. To call one of these routines, the programmer inserts an "RST 7" instruction followed by a 1 byte constant which identifies the desired routine. As an example,

```
RST 7   (Restart 007)
DB 17   (Define Byte 017)
```

calls utility routine number 17, which erases the display screen. The restart 7 data (the "DB 17" above) is used by the monitor to



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index into a "call" or "jump" table. Entries in the table contain the absolute addresses of the utility routines, thereby freeing the programmer from having to deal with absolute addresses. This technique assures that programs which call the monitor system routines will execute properly with all (including future) versions of monitor software. RST 6 has been reserved for the user to construct a similar call table for his or her own use. Two dedicated locations in scratch pad memory are used to specify the starting address of the call table.

And an Eye to Graphics

Another 2 letter monitor command (GR) transfers control to the graphics character generator command processor. Simple keyboard commands allow the user to place any of 256 current character definitions at any screen line and column; create or modify character graphics by defining individual dots within an 8 by 8 matrix; erase the screen; select a graphics color scheme; or save a created set of characters on cassette tape. The characters created in this manner can be used by routines created by the editor and assembler.

Noval BASIC

Noval BASIC is available as a minimal cost option. However, a prerequisite for running this version of BASIC is that the entire system monitor (including the editor, assembler, etc) be installed on PROM. The reason for this requirement is that some of the extended features of Noval BASIC require use of editor and assembler subroutines. Noval BASIC itself occupies 6 K bytes of memory, and is available in both volatile memory and PROM versions. If the PROM version of BASIC is installed, a total of 16 K bytes of systems software resides in a Noval 760.

Consistent with the overall Noval design philosophy, BASIC has been enhanced to take full advantage of system flexibility. Some of the features are graphics character generation and display capabilities; color selection capability; saving and loading programs from cassette tape; listing programs on the printer; fast BCD floating point package; full control of display screen presentations, including cursor positioning; single and double dimensioned arrays; and the ability to call monitor and user assembly language subroutines.

Although the Noval BASIC interpreter is designed to be consistent with the 1974 ANSII standard (which presents a "standard BASIC"), the extra features of this system require some differences. Some of the most useful "extras" of this version concern the use of monitor subroutines and the development of user assembly language subroutines. Noval BASIC allows the user to preset all 8080A registers before a call to an assembly language routine whether it is in the monitor, or user created. Similarly, all registers can be read after the call has been completed. The statement SYS (n) calls system routine number "n." The USER statement provides a similar facility for user defined routines.

About the Manufacturer

Noval was formed about a year ago as a sister company to Gremlin Industries, an established manufacturer of electronic arcade games. The goal of Noval is to provide the personal computing user with the microprocessor technology which Gremlin has developed in-house and refined over a 3 year period. This explains the heavy emphasis in the Noval system on assembly language, graphics and game-oriented features. Additionally, Noval is involved in a continuing research project with the San Diego school system, called Telemath, in which tutorial games are designed around mathematical learning objectives for grade levels 2 thru 6. Out of this effort has evolved a mathematical game library of over 50 programs to date. All Telemath programs are available to Noval system users, as are selected Gremlin Industries arcade games, which until now were rarely seen in homes and offices.■

Interpreting Specs

The effective resolution in each 8 by 8 spot character cell is equivalent to 256 spots horizontally, 224 spots vertically. Keeping one character definition for the "null" (all spots off) condition, and using 255 character definitions for active (nonnull) graphic information, any picture which requires use of less than about 28% of the full screen area for active video information (restricted to the 28 by 32 character cell grid) can be represented. If the picture has repeating subelements which can be programmed into the matrix of character cells, then more of the screen can be covered with meaningful information. Animation graphics can be smoothly represented on this grid by devoting small groups of programmable character cell definitions to picture elements which evolve with time . . . CH

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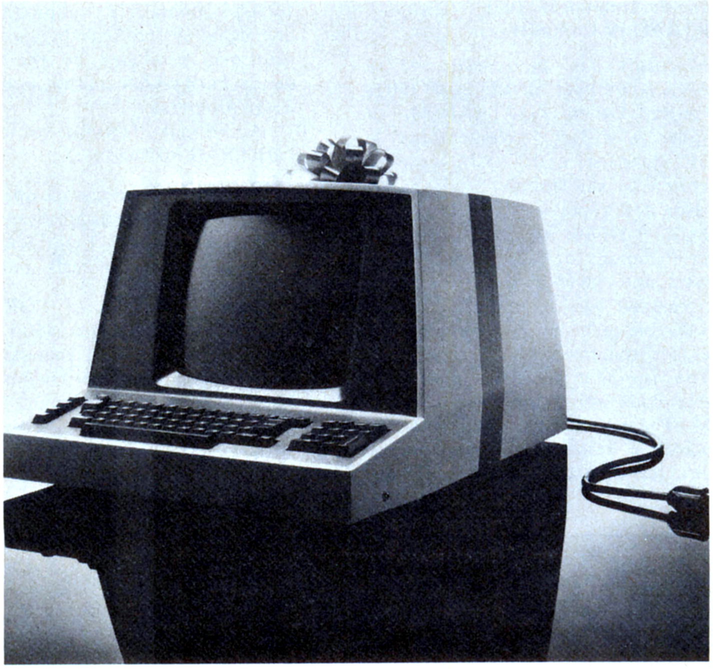

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What's New?

Microsoft Announces 8080 FORTRAN IV Compiler

Microsoft has announced a FORTRAN IV compiler for the 8080 microcomputer. Called FORTRAN-80, the compiler is a full implementation of ANSI Standard FORTRAN with the exception of the double precision and complex data types.

FORTRAN-80 provides three data types including: logical (1 byte), integer (2 byte), and real (4 byte floating point). An extended version of FORTRAN-80 with double precision and complex data types is forthcoming.

The compiler generates pure, relocatable code which may be placed in ROM. The run time package may also be placed in ROM. This 1 pass compiler requires less than 12 K bytes of memory, the run time system less than 6 K bytes.

A relocating linking loader is included with the FORTRAN package so that subprograms may be compiled separately and linked at load time. This also means that only the specific subprograms required are loaded (including system subprograms).

Another part of the package is a relocating assembler and an assembly language debugging program. The assembler may be used to produce FORTRAN compatible subprograms. The debugging system may be used with the load map produced by the loader to debug FORTRAN and/or assembly language programs.

Additional features of Microsoft FORTRAN-80 include:

- Multistatement code optimization.
- Mixed mode expressions.
- All standard FORTRAN library functions for reals and integers.

Individual copies of FORTRAN-80 may be purchased for $500 including documentation. The manual is $15; OEM (original equipment manufacturing) licenses are available. Contact Microsoft, 819 Two Park Central Tower, Albuquerque NM 87108.■

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Prototype Cards for SWTPC 6800 Bus

Two prototyping boards for either wire wrap or soldertail and wiring pencil are now available from Personal Computing Company, Dallas TX. These boards are either IO size or memory size. Since they use Molex connectors at the bus interface, they are compatible with the SwTPC bus structure and mother board. In addition, other connectors are provided to allow off board and IO functions.

The cards are arranged in rows of holes with the holes on 0.1 inch (0.25 cm) centers and the rows on 0.3 inch (0.76 cm) centers; no pads are dedicated to either power or ground; however, power and ground buses are provided throughout the card. Bypass capacitor locations are provided to eliminate power line noise. Two regulators can be installed in special locations on the memory size card. The IO size card has provision for one regulator. The memory size card is $19.95, and the IO size card is $9.95. Contact Personal Computing Company at 3321 Towerwood, Dallas TX 75234.■

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A New Catalog from E & L Instruments

The Complete Bugworks Catalog is the name of E & L Instruments' new publication describing such items as solderless breadboards, op amp designer modules and socket boards. The Bugbooks series, which teaches electronics and microcomputer theory, is also offered. Copies of the catalog may be obtained by writing to E & L Instruments Inc, 61 First St, Derby CT 06418.■

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How to Sell Your Product

The *Handbook on Marketing for Electrical Engineers* is a 127 page softcover manual available from Schoonmaker Associates, PO Drawer, Coram NY 11727, for $25.50. The book discusses the marketing of technical products and covers such topics as product planning, pricing, sales forecasting, publicity and tactics for the small company. Additional titles on related subjects are also available.■

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Computer Warehouse Store Catalog

The Computer Warehouse Store, 584 Commonwealth Av, Boston MA 02215, is perhaps the largest new and used computer equipment store in the world. Their new catalog (of similar proportions) lists a wide range of brand name kit and assembled computer products. In addition, there is much tutorial information along with microprocessor comparison charts and a multitude of onetime bargains. This is a true computer hacker's "wishbook" of useful equipment and accessories. The catalog is available free from the above address.■

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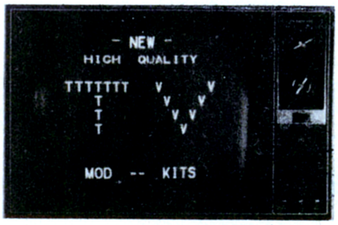

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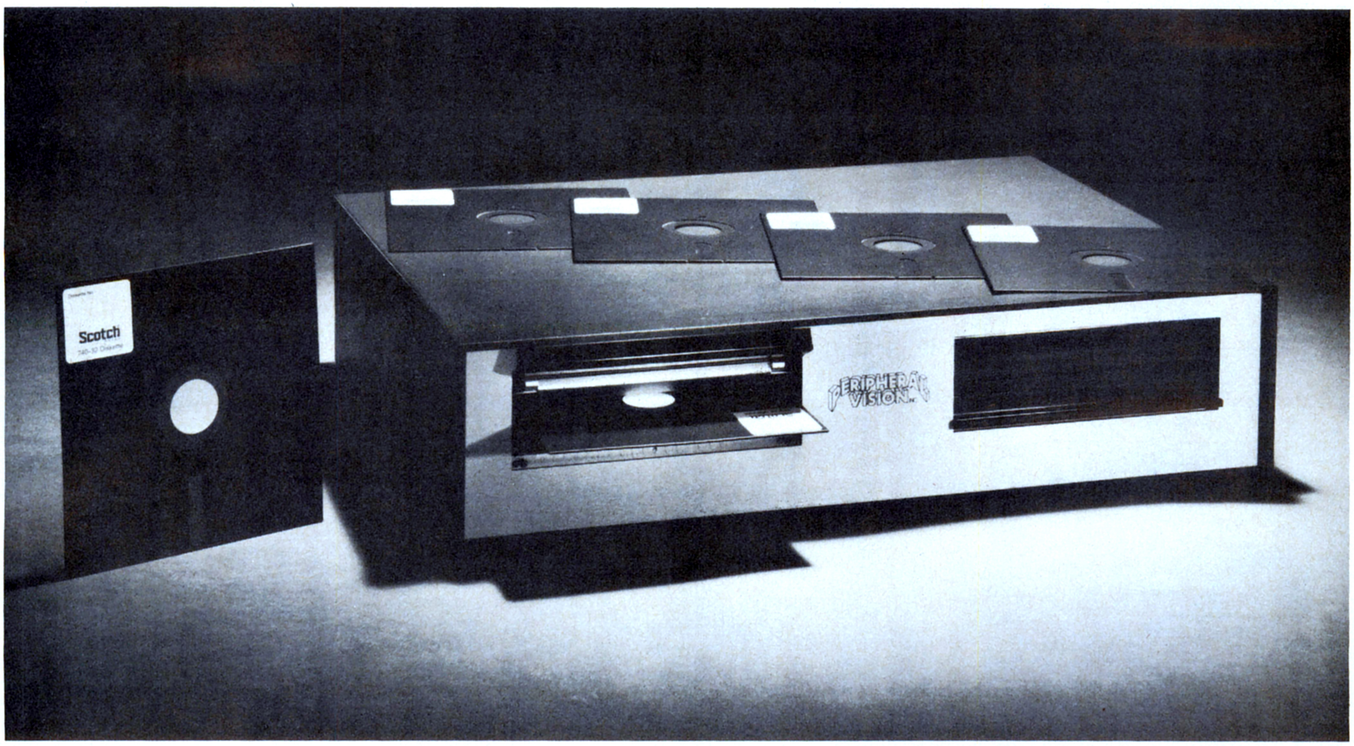

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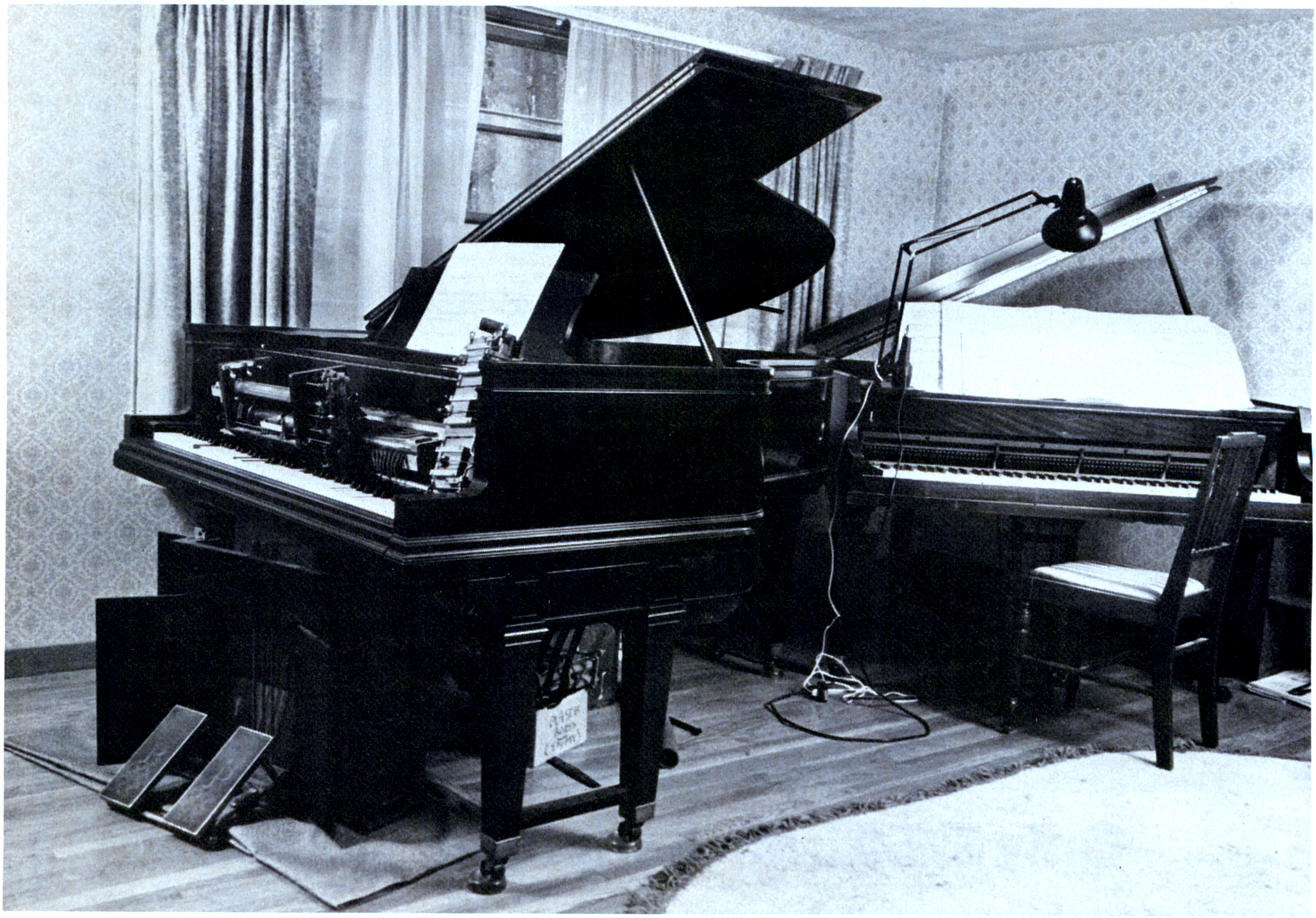


Photo 1: The object of the design exercise documented in this article is an interface between the computer in the basement and the Steinway baby grand player piano shown at the left in this picture. Using the interface of figure 1, and the solenoid valves of photo 2, electronic control of the restored piano will be completed by adding a motor driven bellows unit of later vintage than this 1910 piano. In the picture, various subassemblies have been placed at skewed angles atop the keyboard (spool box and 3 phase wind motor) and underneath (foot operated bellows and pedals). In the restoration of this piano, all the original mechanisms will be preserved, with the electronics interface consisting of an addition to the basic design.

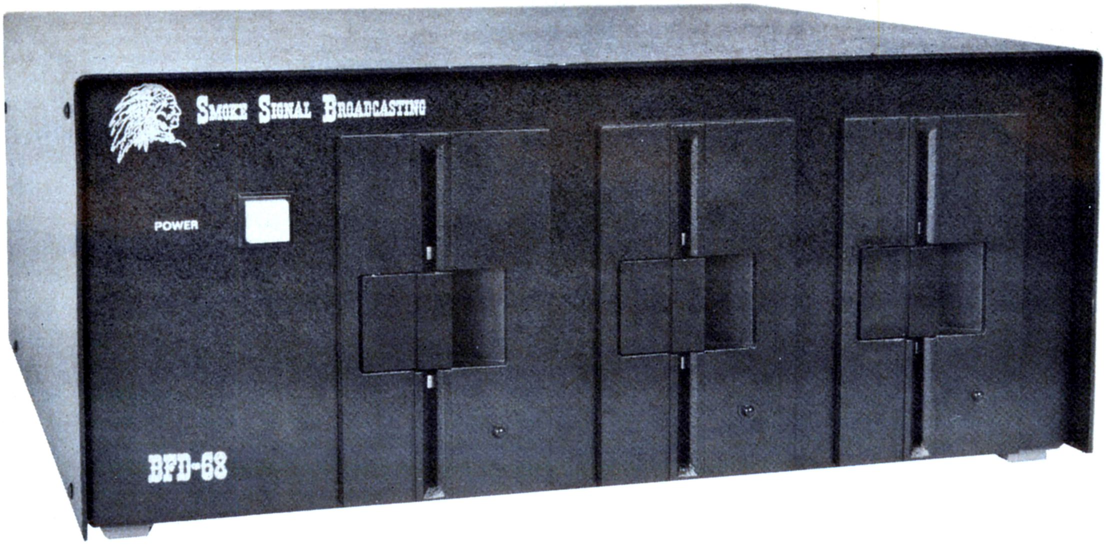
Notes on Interfacing Pneumatic Player Pianos

Carl Helmers
Editor

Everyone is familiar with the concept of the player piano, a complex mechanical monstrosity which had its heyday in the early part of this century as the prime home entertainment device before the invention of electronic media which now dominate the home entertainment scene. But player pianos are far from dead. Just as there is an active subculture of computer aficionados, there is a whole cult of player piano and mechanical music freaks. Thanks largely to these people a working player piano is not an uncommon sight in the parlors, dens and living rooms of contemporary suburbia.

Many of the owners of player pianos may not recognize that these instruments can be a most interesting output device for a personal computer, an output device whose interface can be achieved with very little woodworking and mechanical skill as well as the usual hardware and software skills of the experienced computer hacker.

I have long had an interest in electronic music as generated and controlled by computers. It is this interest which started me on the road to learning electronics hard-



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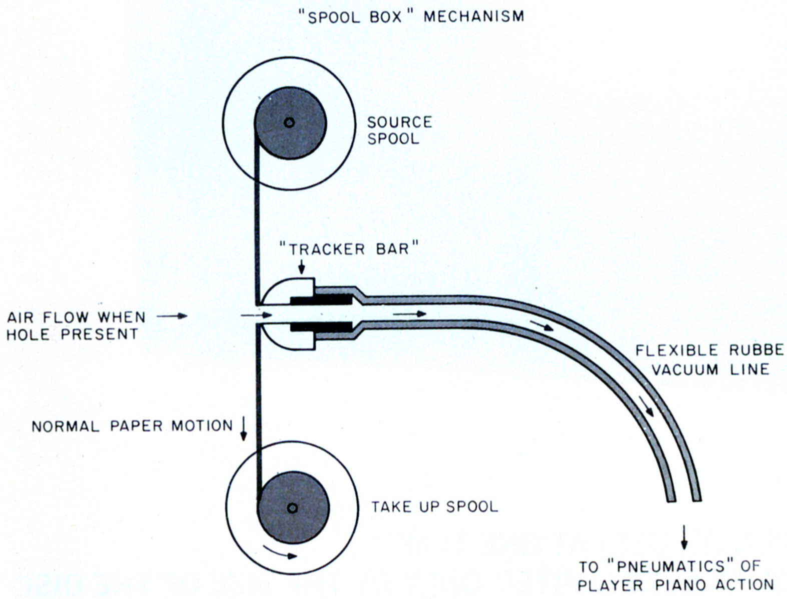
"SPOOL BOX" MECHANISM
SOURCE SPOOL
"TRACKER BAR"
AIR FLOW WHEN HOLE PRESENT
FLEXIBLE RUBBER VACUUM LINE
NORMAL PAPER MOTION
TAKE UP SPOOL
TO "PNEUMATICS" OF PLAYER PIANO ACTION

Figure 1: The normal arrangement of a player piano's vacuum control system is illustrated here. A player piano roll moving past a "tracker bar," analogous to a magnetic tape recorder's read head, turns on and turns off a flow of air into the evacuated control line which goes to one of the pneumatic controls of the piano. For the key mechanisms, the leading edge of loss of vacuum cues the striking of a key, which is held down until vacuum is restored. This occurs when the roll passes to a point which closes off the particular line. For control of a full 88 notes, there are 88 separate "channels" in the tracker bars of the more sophisticated players, not counting additional channels to control dynamics, pedals and other special effects.

ware skills needed to build computers for music control.

I also knew that player pianos existed, and would eventually make an interesting experiment for use with electronic music in programmed performances of concerto style works with orchestral background for the solo instrument provided by electronics. But I had never turned my attention to the details of the piano interface problem until one day in October of 1976 when I went to an estate auction in nearby Milford NH at which a 1910 Steinway-DuoArt baby grand player piano (in unplayable condition) was put on the block. After outbidding a mechanical music box museum owner from Maine, I had the potential for the ultimate piano. When the piano is eventually restored, it will provide my personal and computer music systems with a piano output device which, incidentally, can be used for normal piano rolls, normal practice under direct manual control of the keys, and under computer control using an interface to be described in this article.

The piano, which is shown in photo 1, gave me the impetus needed to examine in more detail the problem of controlling a pneumatic vacuum line with the output of a computer. Figure 1 shows a schematic illustration of the essence of the typical player piano's control mechanism. The player piano roll passes over what is called the "tracker bar" in the jargon of that technology. This tracker bar has one hole for each active key of the piano as well as auxiliary holes for various other types of information which may be encoded on the rolls. When a hole in the roll passes the hole in the tracker bar, the vacuum line associated with the hole is opened to outside air. This release of the vacuum in the line triggers one of the "pneumatics" in a bank under the piano, which is basically a vacuum operated buffer amplifier with enough output power to toggle a key or actuate some other mechanism. The operation of the "pneumatic" is of no great concern at this point, since all we need to know is that if the vacuum line is opened, the key will be struck, and that if the vacuum line is closed, the key will be released and the device will charge up with vacuum, waiting for the next time that key is to be actuated. The conversion to electronic control is simplest if we just adapt the existing mechanism by plugging up the tracker bar holes (temporarily during electronic performance) and adding a "T" junction to each control line so that an electronic control valve can simulate the opening of the vacuum line. Figure 2 shows this adaptation of the usual vacuum line arrangement for electronic control.

Figure 2 also shows schematically the physical arrangement of a flap valve. As I began looking into the problem of controlling air flow, I quickly learned about the existence of electrically controlled pneumatic devices used in pipe organ and piano technology. It turns out that there is a company called Reisner Inc, which among other items makes a specialty of manufacturing and selling control valves for player pianos and pipe organs. Photo 2 shows the model for the schematic rendition in figure 2, a Reisner No 601-90 magnet with 5/8 inch valve mounted for the purpose of testing on a scrap of pine board, with a metal standoff used as the junction fitting to connect to the vacuum line. The Reisner subassembly consists of everything you see attached to the metal frame which is screwed to the top of the wood block: the magnet, the upper valve seal with cushions for sound dampening, and the return spring. In adapting this unit to a player piano's purposes, a bank of these valves is required, with a number depending upon the details of the particular piano. (For more complete

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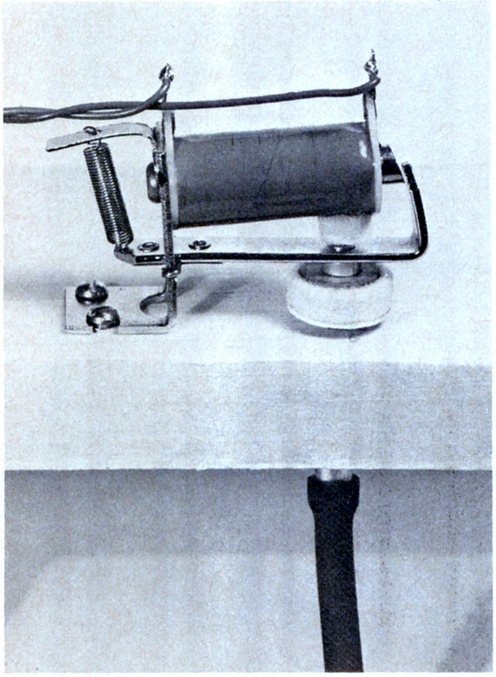

Photo 2: A test jig used to try out the magnetic control valve concept. The Reisner No. 601-90 magnet with 5/8 inch valve is mounted on a wood block using wood screws. In a final installation as part of a multiple valve attachment to a player piano's penumatics, one such valve would be assigned to each control tube of the piano.

information on these valves, contact Reisner Inc, 240 N Prospect St, POB 71, Hagerstown MD 21740.) The physical mounting of the valve magnets, tubing, etc, depends upon the particular piano being converted. In the case of my baby grand player, an equipment chest will probably be attached under the sounding board in back of the presently installed pneumatics chest. Some woodworking ability and some mechanical handiwork are required in the fabrication of a bank of valves and in making the interconnections to the vacuum lines.

Electrical Drive and Interface

The era of integrated circuits simplifies the basic problem of controlling the sole-

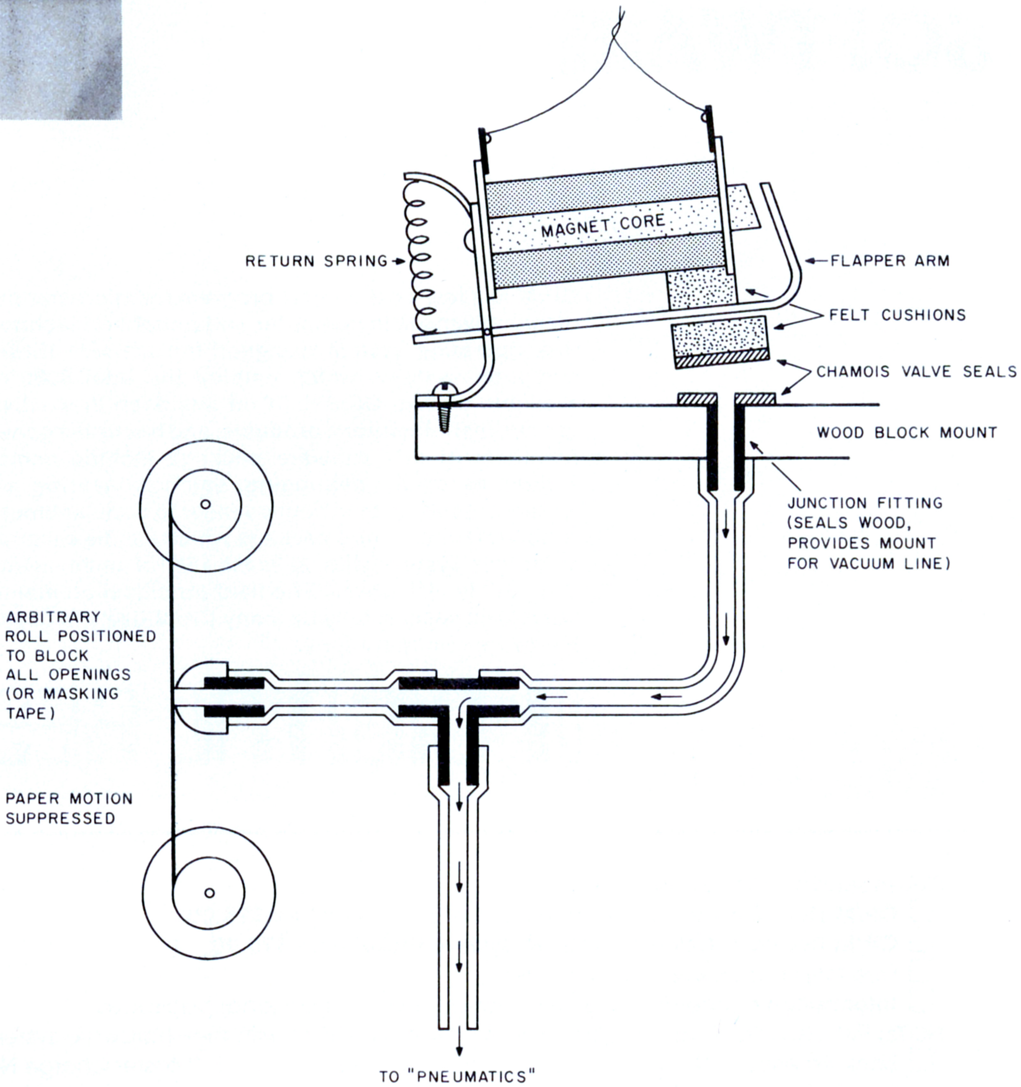
MAGNET CORE
RETURN SPRING
FLAPPER ARM
FELT CUSHIONS
CHAMOIS VALVE SEALS
WOOD BLOCK MOUNT
JUNCTION FITTING (SEALS WOOD, PROVIDES MOUNT FOR VACUUM LINE)
ARBITRARY ROLL POSITIONED TO BLOCK ALL OPENINGS (OR MASKING TAPE)
PAPER MOTION SUPPRESSED
TO "PNEUMATICS"

Figure 2: Adapting the player piano mechanisms for computer control is accomplished using Reisner magnets and flapper valves. Each tube from the tracker bar is modified with a "T" junction which allows an alternate control point on the vacuum line. When the piano is run in computer control mode, all the holes in the tracker bar are sealed and the solenoid controlled valves simulate the effects of the roll's passage over the bar. The sealing of the bar can be accomplished by pasting a run of masking tape over the bar or by disabling the spool box's drive motor and positioning a roll's leader over the tracker bar to close all the holes. For details of the valve, see photo 2. A basic interface drive circuit for the solenoid is shown in figure 3.

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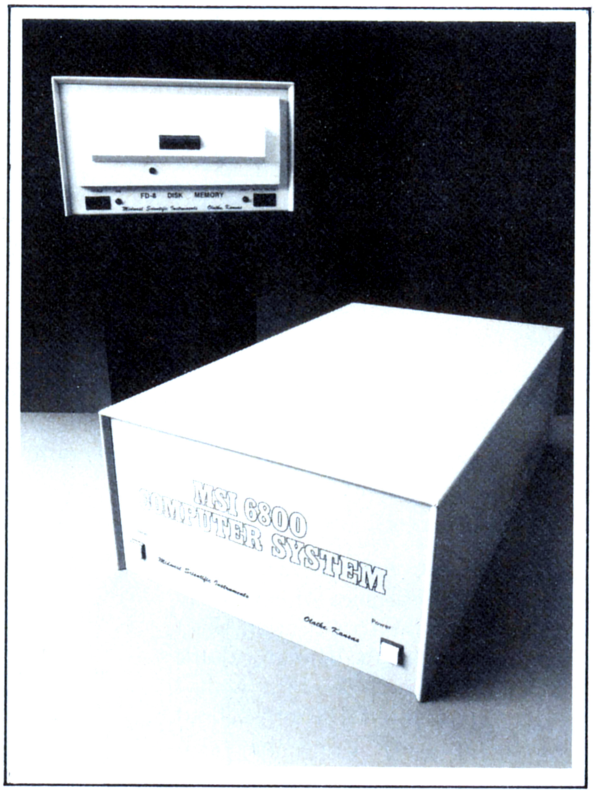
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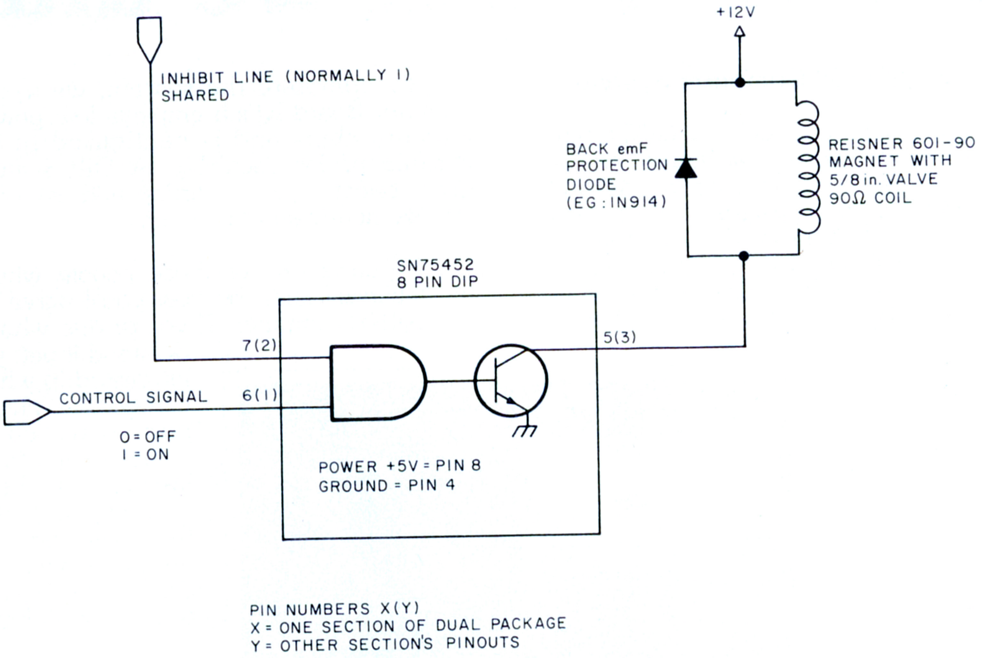

Figure 3: The basic magnet drive circuit used for the pneumatic player piano interface. The driver circuit shown here is a Texas Instruments SN75452, a dual peripheral driver which comes in a miniature 8 pin dual inline package. Each driver has a maximum capability of sinking 300 mA in the low level output state (logical 1 input which "turns on" the magnet). With the nominal 90 ohm coil and a low level output of 0.25 V the coil will have 11.75 V across it. The current through the coil is thus 130 mA, more than enough to actuate the valve based on experiments with the unit shown in photo 1 which was tested against a vacuum applied to valve through the rubber hose.

noids of the Reisner magnet valves. The solenoid coil has a resistance of nominally 90 ohms, and from the specification sheet (confirmed by tests in my laboratory) the valves can be actuated under load with a current higher than about 100 mA (about 9 V across the magnet). Using the *Texas Instruments Linear and Interface Circuits Data Book* as the source of information, it soon became apparent that the 75452 peripheral driver circuit (or its cousin, the 75451) would prove quite adequate for the job since it can sink 300 mA and has a maximum voltage rating well above the voltage required for the actuation of the magnets. The basic circuit for driving a solenoid with the 75452 integrated circuit is shown in figure 3. In this illustration, I have shown one of the two gate inputs as an inhibit signal (normally at logic level 1) and the other input pin as the control signal defined so that if it is low (logic 0) the magnet is off (valve closed) and if it is high (logic 1) the magnet is on (valve open). The diode mounted on the solenoid coil is an absolute requirement. These magnets have a considerable inductance, and as a result when the current is removed will generate a substantial back EMF which can damage the 75452 output transistor if it is not shorted out by the diode. (The inductance is sufficient to cause an impulse which can be felt by the observer if fingers are held across the coil while the voltage is removed. This suggests a minimum of 50 to 100 V of inductive "kick.")

Logic of a Practical Interface

The brute force technique of interfacing the piano would be to simply put one wire from a latched output bit to each driver of the piano magnets, resulting in roughly 80 to 100 twisted pair interface data paths in a monstrously thick cable. This is an unwieldy mess. The problem is shared by pipe organ aficionados, as I found out from Jeff Raskin's lecture at the First West Coast Computer Faire's session on computers and music in April of this year. At that time he suggested the use of a serial technique to define the state of a bank of control valves. Basically, the technique consists of using serial synchronous transmission from the computer to cut down on the immense number of lines which would otherwise be required. Figure 4 shows a detailed sketch of

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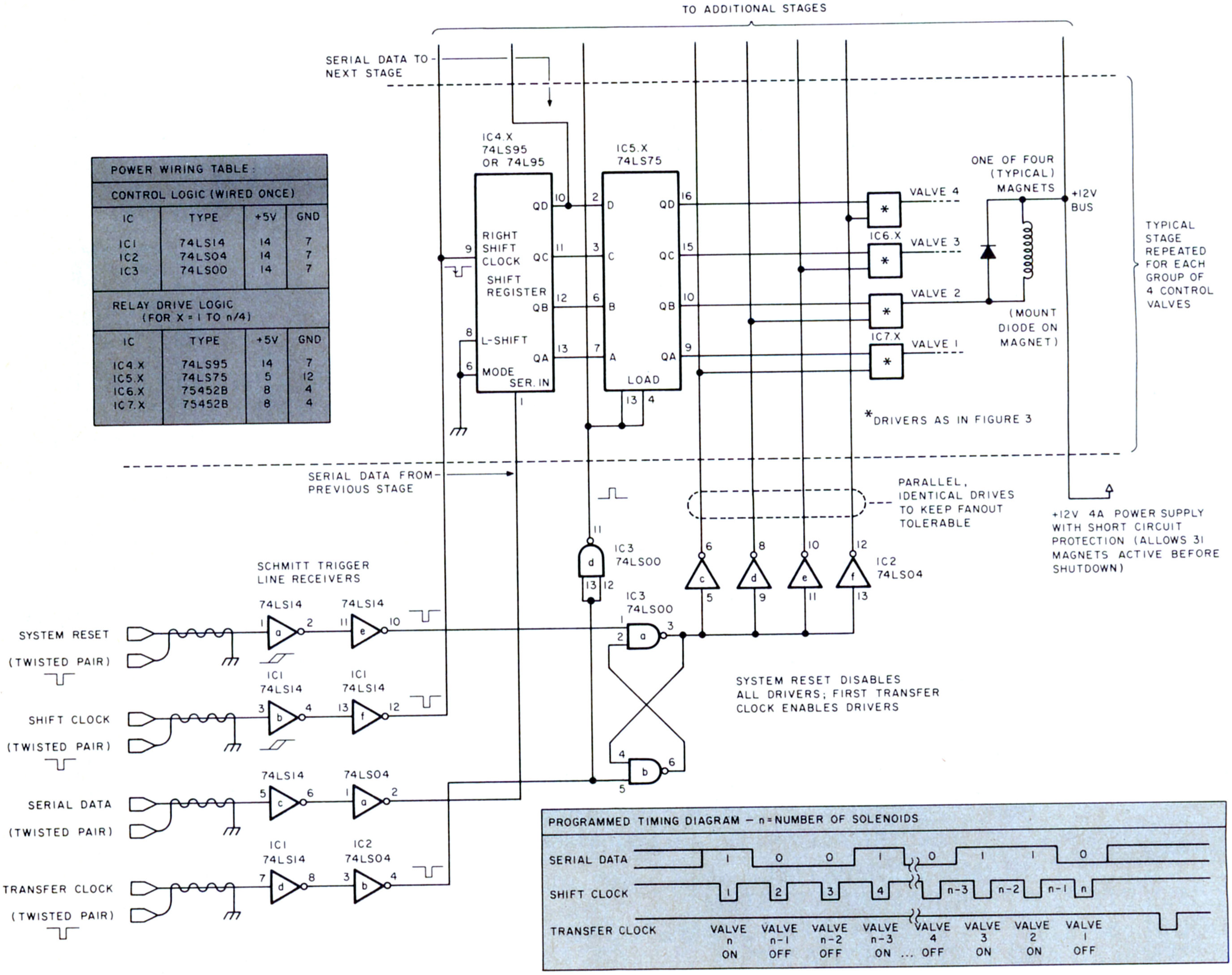

TO ADDITIONAL STAGES
SERIAL DATA TO NEXT STAGE
IC4.X 74LS95 OR 74L95
RIGHT SHIFT CLOCK
SHIFT REGISTER
L-SHIFT
MODE
SER. IN
QD
QC
QB
QA
IC5.X 74LS75
D
C
B
A
LOAD
ONE OF FOUR (TYPICAL) MAGNETS
+12V BUS
VALVE 4
VALVE 3
VALVE 2
VALVE 1
IC6.X
IC7.X
(MOUNT DIODE ON MAGNET)
TYPICAL STAGE REPEATED FOR EACH GROUP OF 4 CONTROL VALVES
*DRIVERS AS IN FIGURE 3
SERIAL DATA FROM PREVIOUS STAGE
PARALLEL, IDENTICAL DRIVES TO KEEP FANOUT TOLERABLE
+12V 4A POWER SUPPLY WITH SHORT CIRCUIT PROTECTION (ALLOWS 31 MAGNETS ACTIVE BEFORE SHUTDOWN)
IC3 74LS00
IC2 74LS04
SCHMITT TRIGGER LINE RECEIVERS
74LS14
74LS04
IC1
IC2
SYSTEM RESET (TWISTED PAIR)
SHIFT CLOCK (TWISTED PAIR)
SERIAL DATA (TWISTED PAIR)
TRANSFER CLOCK (TWISTED PAIR)
SYSTEM RESET DISABLES ALL DRIVERS; FIRST TRANSFER CLOCK ENABLES DRIVERS
PROGRAMMED TIMING DIAGRAM — n=NUMBER OF SOLENOIDS
SERIAL DATA
SHIFT CLOCK
TRANSFER CLOCK
1 0 0 1 0 1 1 0
1 2 3 4 n-3 n-2 n-1 n
VALVE n ON
VALVE n-1 OFF
VALVE n-2 OFF
VALVE n-3 ON ...
VALVE 4 OFF
VALVE 3 ON
VALVE 2 ON
VALVE 1 OFF

POWER WIRING TABLE:

CONTROL LOGIC (WIRED ONCE)

IC	TYPE	+5V	GND
IC1	74LS14	14	7
IC2	74LS04	14	7
IC3	74LS00	14	7

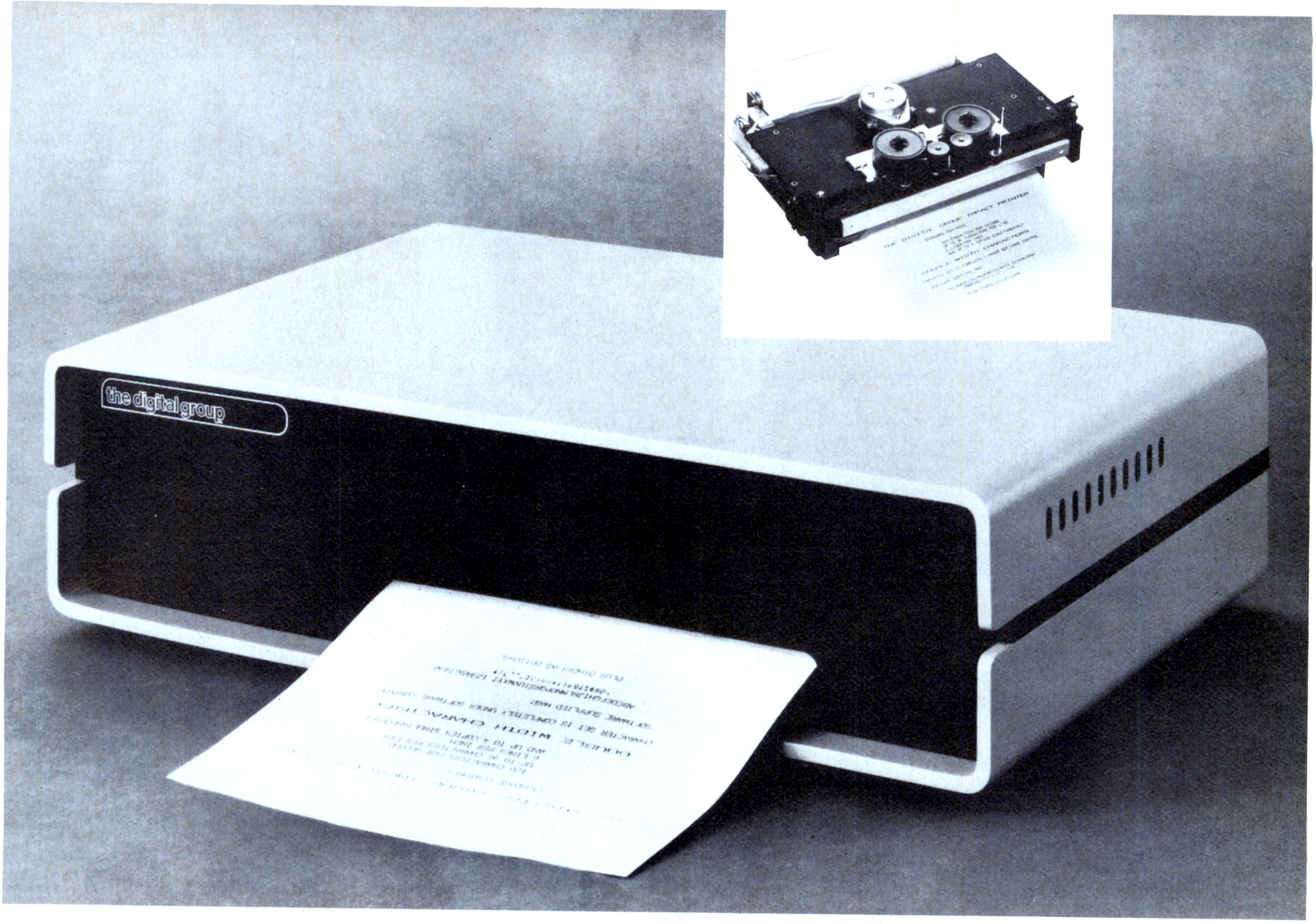
RELAY DRIVE LOGIC (FOR X = 1 TO n/4)

IC	TYPE	+5V	GND
IC4.X	74LS95	14	7
IC5.X	74LS75	5	12
IC6.X	75452B	8	4
IC7.X	75452B	8	4

Figure 4: Solving the problem of heavy interconnection cables. This diagram shows a synchronous serial transmission scheme which requires four twisted pair wires to connect a parallel output port with the piano for programmed serial transfers. One twisted pair cable is dedicated to the system reset line so that the local electronics in the piano will turn off all drivers when the system is reset. The other three lines are connected to three output bits. One bit is programmed with the successive bits of data for the various valves when an output transfer is done. After each data bit is defined, the shift clock line is toggled to push its value down the 88-100 or so shift register stages assigned to control the 88 to 100 valves used in the piano. Then, when all the bits have been defined in successive operations, the transfer clock line is toggled to parallel load all the control latches and define the state of the solenoids. With a programmed transfer loop on a typical microprocessor, no more than 50 µs per bit should be required, or an update time of 5 ms per 100 solenoid data transfer under program control. This gives the processor a limiting resolution of 1/200th of a second, well within the timing accuracy needed for music. Using specialized transmission hardware to automatically serialize the data from 8 bit bytes would speed up the typical data rates if needed.

the logic I designed which will enable this method of interfacing to be employed with three signal lines from a parallel output port of the control computer. In this scheme, each group of four valves is assigned one 4 bit shift register segment and a latch which can be loaded from the shift register. This module of four bits works out very well with the widely available TTL MSI technology shown. The entire bank of n/4 such modules defines an n bit shift register with an n bit latch in parallel. Transfers of new information are accomplished (see timing diagram) under program control by shifting out n bit

Continued on page 168



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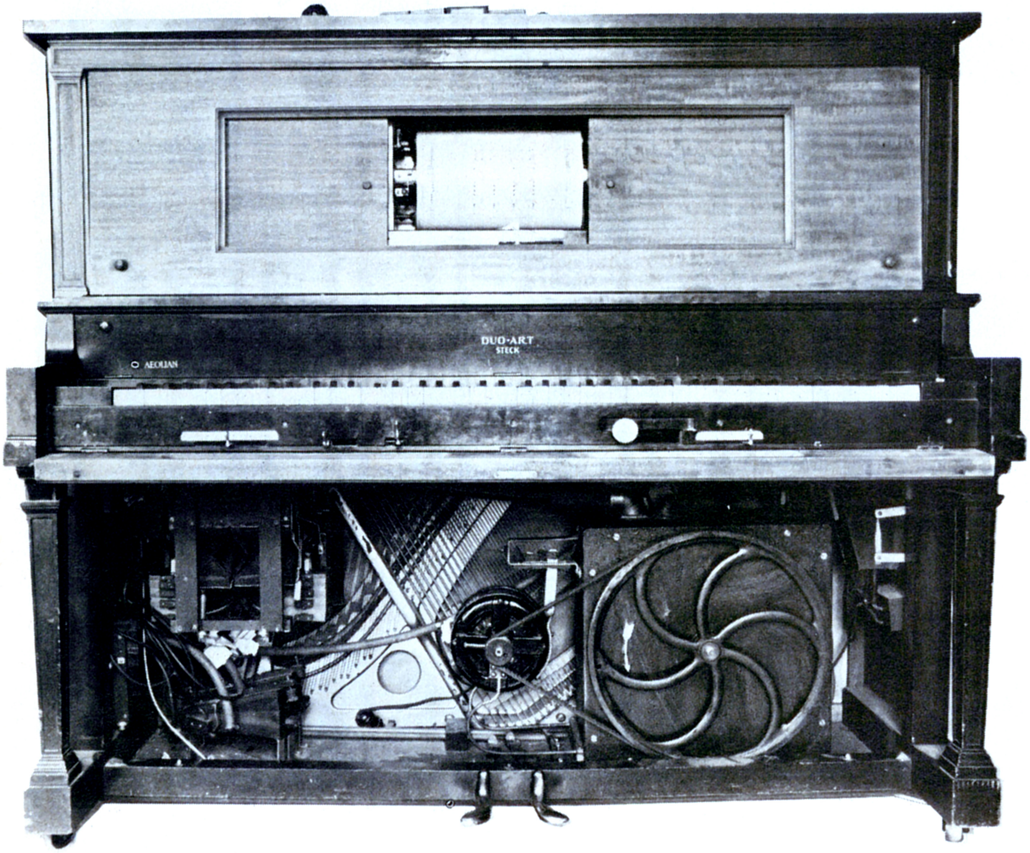


Photo 1: The Duo-Art reproducing player piano as it is currently displayed in my home. Notice the electric motor at bottom center. It is original equipment. The vacuum pump is at the right; it is connected to the motor by a 1968 V8 Buick fan belt, which just happens to be a perfect fit. The piano was built in 1925 and required extensive renovations. The binary dynamics control system is located at bottom left (see photos 3a and 3b).

The Piano's Reproductive System

By Chris Morgan, Editor

When was the binary number system first used for control purposes in a mass produced machine? The early nineteenth century Jacquard punch card controlled loom comes immediately to mind; but, surprisingly enough, a more widespread application occurred in the first quarter of this century: the reproducing player piano!

The reproducer was so-called because it went one step beyond the player piano in its ability to "reproduce" the dynamics and subtle shadings of the pianist who recorded the roll.

I have owned a Duo-Art upright reproducing piano for five years now (see photo 1), during which time I have restored it so that it can now play the specially encoded Duo-Art rolls which were made for it. The Duo-Art roll catalog was remarkably extensive, featuring such items as Chopin etudes and Beethoven sonatas in addition to a large selection of popular titles. (The pièce de résistance was a complete set of themes from Wagner's Ring cycle comprising some 30 odd rolls!).

Reproducers were a luxury item during the 1920s, and for good reason: they were built like fine watches and contained some fairly sophisticated features (for the time) to control dynamics, operate the pedals, and so on.

Photo 1 shows the Duo-Art with the bottom cover removed for clarity. The spool box (photos 2a and 2b) is located at the top and is the place where the piano roll is inserted. Immediately below the keyboard are the levers which are used to control the speed of the roll as it plays, as well as volume and roll rewind. At the bottom center is the original electric motor (built in 1925) which drives the vacuum pump at the right. No pedalling is required on this model, a boon for the lazy experimenter. Like most player pianos, the Duo-Art works on a vacuum actuated system which opens and closes cloth covered "pneumatics," or bellows. These in turn do all the mechanical work inside the piano, such as playing keys and operating pedals.

But what makes the Duo-Art so interesting is its binary-based volume control system located in the lower left section of the piano (see photos 3a and 3b for a close-up). There are two independent volume control systems built into the Duo-Art. They are controlled by two sets of four holes per set, located above the main row of holes near each end of the tracker bar. Photo 4 shows the right-hand set of holes in enlargement. Notice that they are vertically in line with the four highest note sensing holes on the tracker bar. When a Duo-Art roll is played, therefore, a special pneumatic 8 pole double throw switch must be thrown to disable the lower two sets of four holes and allow the upper two sets of four holes to control piano dynamics (the volume of sound heard).

Each set of holes is connected to a set of "accordion" pneumatics, so-called because they open and close like vertical accordion bellows. A rod at the top of each pneumatic is connected to an air governor. As the pneumatics close, the governor admits more and more air to the system and the volume of the notes played on the controlled side of the keyboard goes up.

The spacings of the four sections of the pneumatics are 1/2, 1/4, 1/8 and 1/16 inch, so that 16 different volume levels can be achieved. This bellows is in fact a form of mechanical digital to analog converter. So we have two nybbles (or one byte) of information to control volume in a Duo-Art reproducer piano. Photo 3b shows a level corresponding to 1/2 + 1/8, or 10/16ths of maximum volume, and photo 3a shows a zero level for comparison. Photo 5 shows the roll positioned to produce the level of photo 3b; the most significant bit is to the left. Since an opening (hole) corresponds to a binary 1 level, the binary number here is 1010.

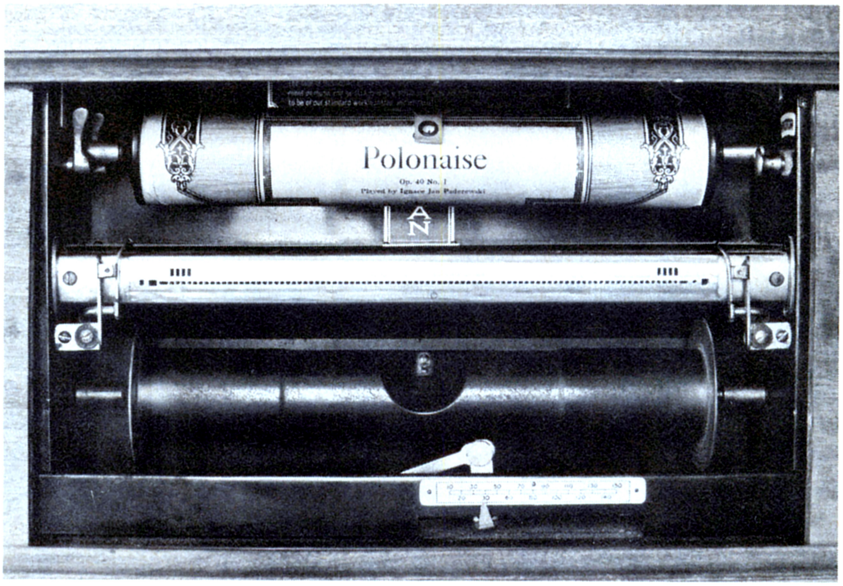


Photo 2a: The spool box, showing the brass tracker bar. There are 88 holes across the bar, corresponding to the notes of the piano. There are additional holes at each end to input two 4 bit "nybbles" of information to the dynamics (volume) control system from the paper roll.

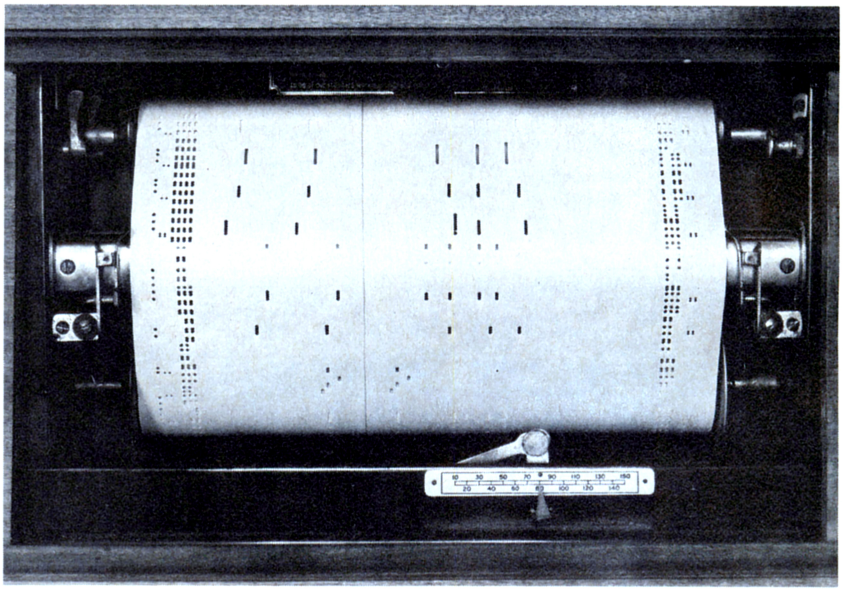


Photo 2b: A view of the spool box with a Duo-Art roll installed. Note the dense groups of holes at each side of the roll; these contain binary encoded information about the volume of the notes which are being played. All four dynamics holes are about to be uncovered on the left side as the roll paper moves downward across the tracker bar. (Thus maximum volume is about to be set up.) The dynamics holes appear as groups of holes rather than long slots so that the paper will not fall apart. The tracker bar holes underneath are long enough so that the small paper bridges left for mechanical strength do not close up the holes as they pass over them.

Counting from the right in photo 4, the first 3 holes are mute pedal control, automatic reroll and the "theme" hole. The theme hole is an ingenious feature. There are often cases when the piano must suddenly change volume levels for isolated notes or chords and then return to the previous level. It takes a finite time for this sort of change, so the rolls are designed to allow the left-hand accompaniment dynamics control system to control the entire keyboard range, while the right-hand theme system "charges" itself with vacuum for the up-

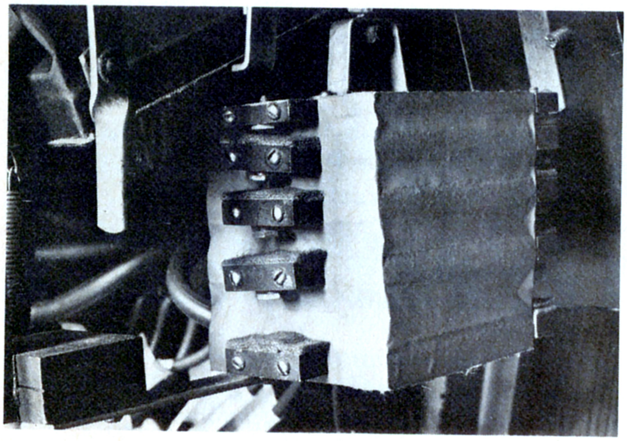


Photo 3a: One of the two Duo-Art accordion pneumatics used to control the volume of one half of the piano keyboard. Each of the four chambers can be individually exhausted under control of the piano roll. The pneumatic is connected by a rod on top to an air governor. The four chambers close by 1/2, 1/4, 1/8 and 1/16 inches, so that the air governor can be set to any of 16 different vacuum levels to power the keyboard pneumatics. The roll's 4 bit binary "word" is thus translated into a vacuum level: in effect, this is a digital (vacuum lines from tracker bar) to analog (mechanical position of governor) converter.

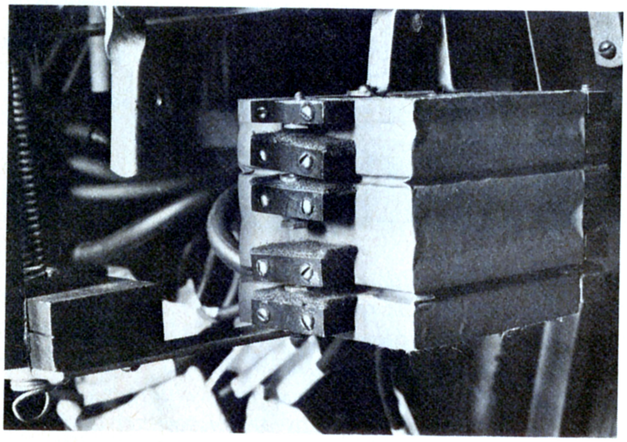


Photo 3b: The accordion pneumatic shown converting the integer value 10 into one of 16 possible mechanical positions. This corresponds to the binary number 1010 on the roll. See photo 5.

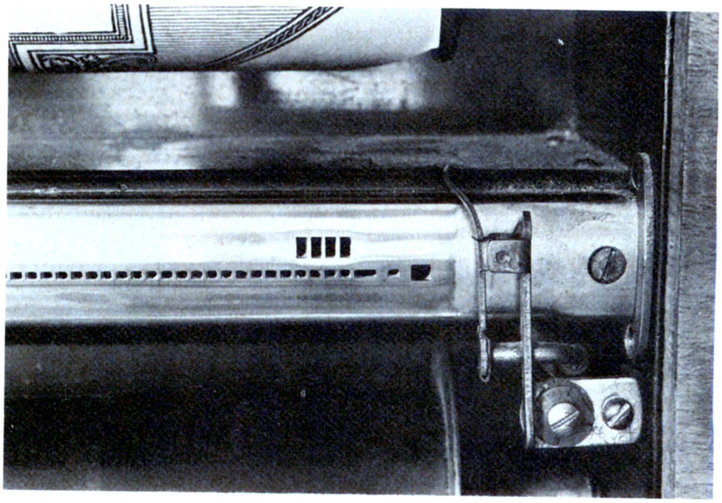


Photo 4: A closeup illustrating the four right hand dynamics control holes, located slightly above the center line of the rest of the holes.

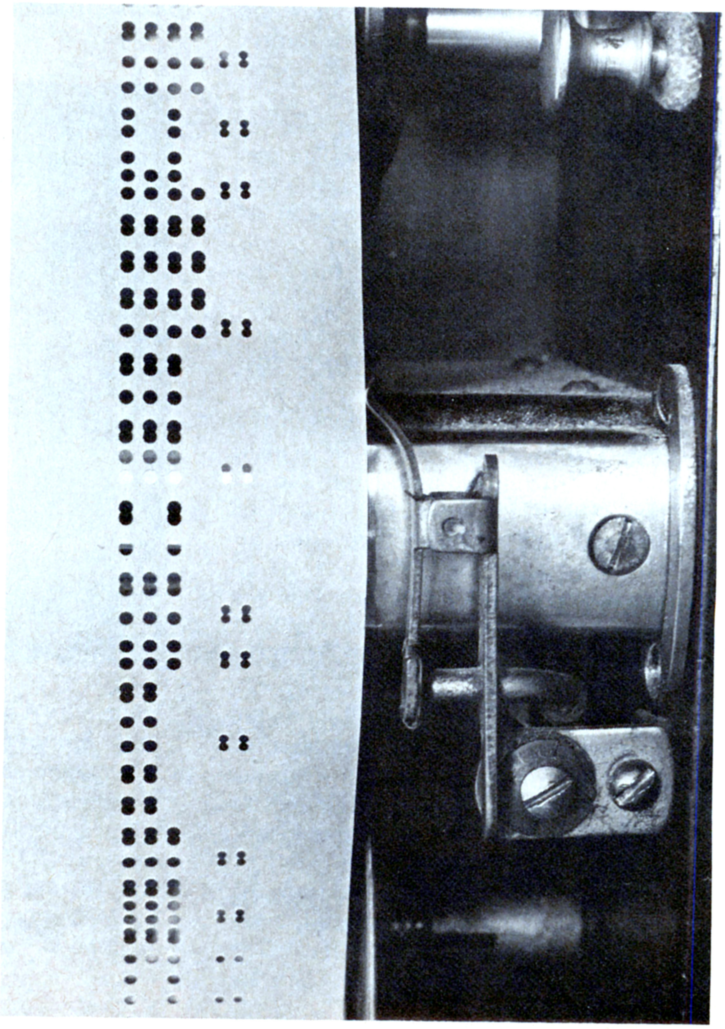


Photo 5: The roll in this case is outputting level ten to the accordion pneumatics. Photo 3b indicates the resulting mechanical position output of the pneumatics.

coming volume change. When the roll triggers either or both of these holes, control of the respective sides of the keyboard is transferred for that instant to the theme control. Details of this theme control system are essential to the design of software drivers for Duo-Art players converted to computer control.

Numerous other fascinating features abound on this instrument. Take for example the automatic roll-centering negative feedback system. The curved vertical "finger" shown in photo 5 is one of two which are positioned to just touch the edges of the roll. If the roll wanders off to the right or left, the fingers tilt back, uncovering air tubes which are under vacuum. This sends a signal to a set of opposing bellows with a high damping ratio, which push the roll spool back until the air tube is covered again. The design is simple, yet effective. Long before Norbert Wiener made it explicit, servomechanisms as control systems were in practical daily use.

Just how good does the Duo-Art sound? Well, it has some obvious limitations (limited dynamic range, for one), but on the whole it sounds remarkably good. The sound quality is several orders of magnitude better than the "new fangled" phonograph which eventually supplanted it commercially.

In its heyday, the Duo-Art Company could afford to hire some of the most famous pianists of the age to record for them: Paderewski (see photo 6), Wanda Landowska, Vladimir Horowitz (when he was in his twenties), Igor Stravinsky (!), George Gershwin (playing his own four-hand arrangement of "Rhapsody in Blue" by overdubbing), and on and on. The rolls were beautifully decorated, too (see photo 6).

Readers wishing to find out more about the fascinating hobby of reproducing pianos should write to the Vestal Press, POB 97, Vestal NY 13850, and ask for their catalog. The Vestal Press specializes in books about player pianos and other musical automata. The Player Piano Company in Wichita KS is an excellent source of supplies for the do-it-yourself restorer. The current bible in the field is *Rebuilding the Player Piano*, by Larry Givens, published by Vestal. In it you'll find valuable material about the Duo-Art and about the other brands of competing reproducers like the Ampico and Wurlitzer models. But that's another story.■

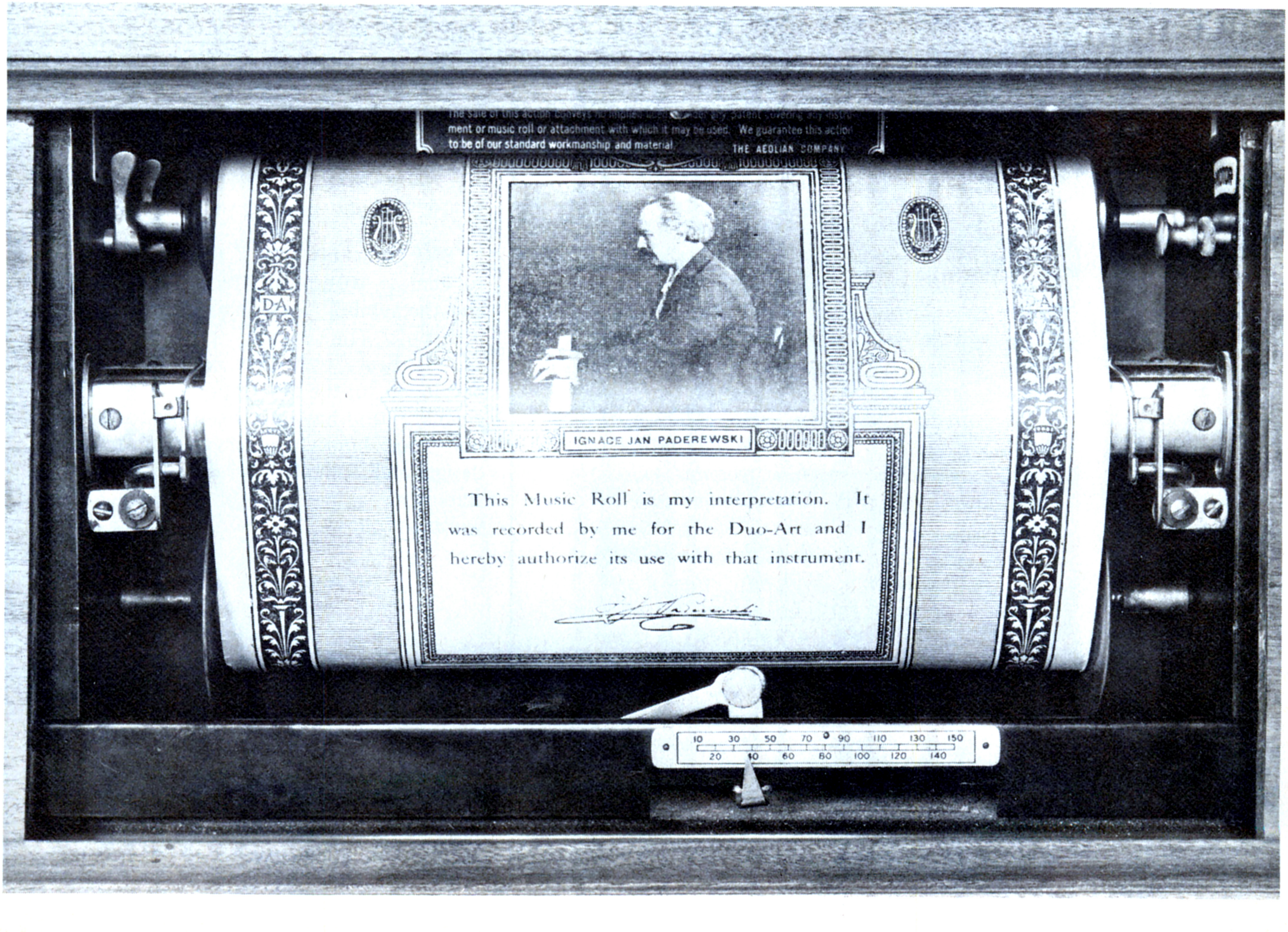

ment or music roll or attachment with which it may be used. We guarantee this action
to be of our standard workmanship and material
THE AEOLIAN COMPANY
DA
IGNACE JAN PADEREWSKI
This Music Roll is my interpretation. It
was recorded by me for the Duo-Art and I
hereby authorize its use with that instrument.
10 30 50 70 90 110 130 150
20 40 60 80 100 120 140

Photo 6: A Duo-Art roll of Chopin's "Polonaise, Opus 40, Number 1," as played by Paderewski, in position over the tracker bar. Note the extensive ornamentation, both visually and verbally, in the form of the performer's authorization of the work. This roll is approximately 55 years old. Paderewski was a link in a liszt of salon pianists which began in America with Louis Moreau Gottschalk, and which continues to this day with certain candelabra wielding virtuosos.

A note on the organization of this article: Because of the large number of figures in this article, the procedure used in part 1 last month is continued this month, ie: the text has been incorporated into the figure and table captions. We hope this will eliminate unnecessary page turning. The figure and table numbering sequence used in this installment continues the sequence begun in the first part. The final part of this 3 part article will appear next month.

Mike Wimble
6026 Underwood Av SW
Cedar Rapids IA 52404

An APL Interpreter for Microcomputers

Part 2: Evaluation Expression

The Great APL Interpreter Contest

As an incentive to those experimenters who would like to try writing their own APL interpreters based on this series of articles, BYTE announces the Great APL Interpreter Contest. We will award prizes for APL interpreters (suitable for publication with royalties to authors) based on Mike's flowcharts (or independent of them if you prefer).

Contestants are free to write their interpreters for any microprocessor they choose. Entries will, however, be judged on their suitability for use on small systems with a minimum of 16 K bytes of memory, as well as on programming elegance and efficient use of space. All of these factors should therefore be kept in mind.

Entries should be addressed to BYTE, attn: The Great APL Interpreter Contest, 70 Main St, Peterborough NH 03458 and must be postmarked no later than midnight, February 28 1978. Entries must be in the form of a publication quality manuscript which describes the implementation of the interpreter and which includes a listing of source code and object code. Contestants should also submit machine readable source and object code in the form of paper tape or cassette.

The winners (if any) will receive $1000 plus normal author payments, should the entry be chosen for publication in book form or as an article in BYTE. We reserve the right to choose more than one winner under the same terms.

Judging will be done by the editors of this magazine. Those seriously interested in entering this contest should call Carl Helmers or Chris Morgan at BYTE, 603-924-7217. May the midnight oil burn prosperously for all.

Backus-Naur Form (BNF)

BNF is a notation used quite often in the description of computer language grammar and semantic information. Many of the figures in this series of articles contain a short BNF description of the formal elements of APL treated by the flowchart in question. A BNF statement looks like:

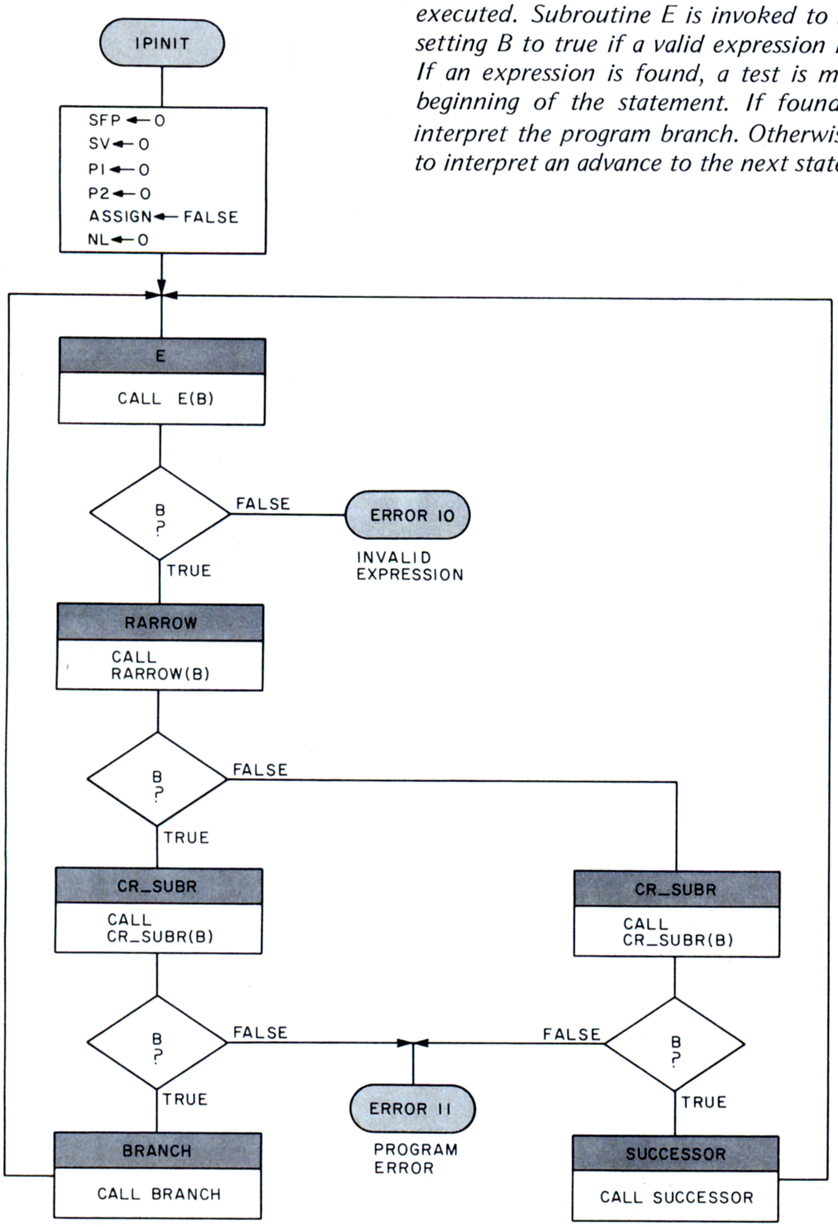
$$<A> \ ::= \ <B> | <C> | <A> \ <B>$$

In BNF, brackets (" < " and " > ") are used to enclose tokens or "terminal elements," and the symbol ": :=" means "may be composed of." The symbol " | " is the notation of a logical "or." This notation was first developed for the description of the ALGOL language, and has since been used widely in numerous books and papers on language design and compiler writing. The example statement above can be translated into words as follows:

> "An A token is composed of either a single B token, or a single C token, or an A token followed by ("concatenated with") a B token."

There is no restriction against possible recursion in BNF syntax descriptions, a feature which allows very simple language constructs to form very complicated statements which can be correctly parsed by the interpreter or compiler.

Figure 11: The logic of the statement interpreter. At this level the interpreter recognizes the two valid forms of a statement: either an expression, or a right arrow followed by an expression. When interpretation begins, variable I points to the rightmost byte in table SP of the immediate statement to be executed. Subroutine E is invoked to recognize and interpret an expression, setting B to true if a valid expression is found, and setting B false otherwise. If an expression is found, a test is made for a right arrow occurring at the beginning of the statement. If found, subroutine BRANCH is invoked to interpret the program branch. Otherwise, subroutine SUCCESSOR is invoked to interpret an advance to the next statement.


IPINIT
SFP ←0
SV←0
P1←0
P2←0
ASSIGN← FALSE
NL←0
E
CALL E(B)
B ?
FALSE
TRUE
ERROR 10
INVALID EXPRESSION
RARROW
CALL RARROW(B)
B ?
FALSE
TRUE
CR_SUBR
CALL CR_SUBR(B)
B ?
FALSE
TRUE
CR_SUBR
CALL CR_SUBR(B)
B ?
FALSE
TRUE
ERROR 11
PROGRAM ERROR
BRANCH
CALL BRANCH
SUCCESSOR
CALL SUCCESSOR

<statement> : : = <expression> |
→ <expression>

Table 8: A table of tables built and used by the statement interpreter. Whenever a subroutine is invoked, SFP is incremented by 1 and table SF is modified. SFP then indicates the current level of nesting or of recursion. If SFP is 0, the interpreter is presently executing a syllable in the immediate mode statement. Pointers to the value of operands for the various operators are stacked in table SVAL much as in any stack-oriented expression evaluator. Tables SD1 and SD2 are used to hold pointers to the right and left arguments of a function call.

Table	Indexed By	Element	Description
SF	SFP		Holds information for subroutine calls.
		S1	Points to FTAB entry of subroutine invoked.
		S2	Value of I (last interpreted syllable pointer) for calling subroutine.
		S3	Statement number of calling subroutine at time of subroutine call.
SVAL	SV		Holds stacked pointers to value of operands.
SD1	P1		Holds stacked pointer of left actual parameter.
SD2	P2		Holds stacked pointer of right actual parameter.

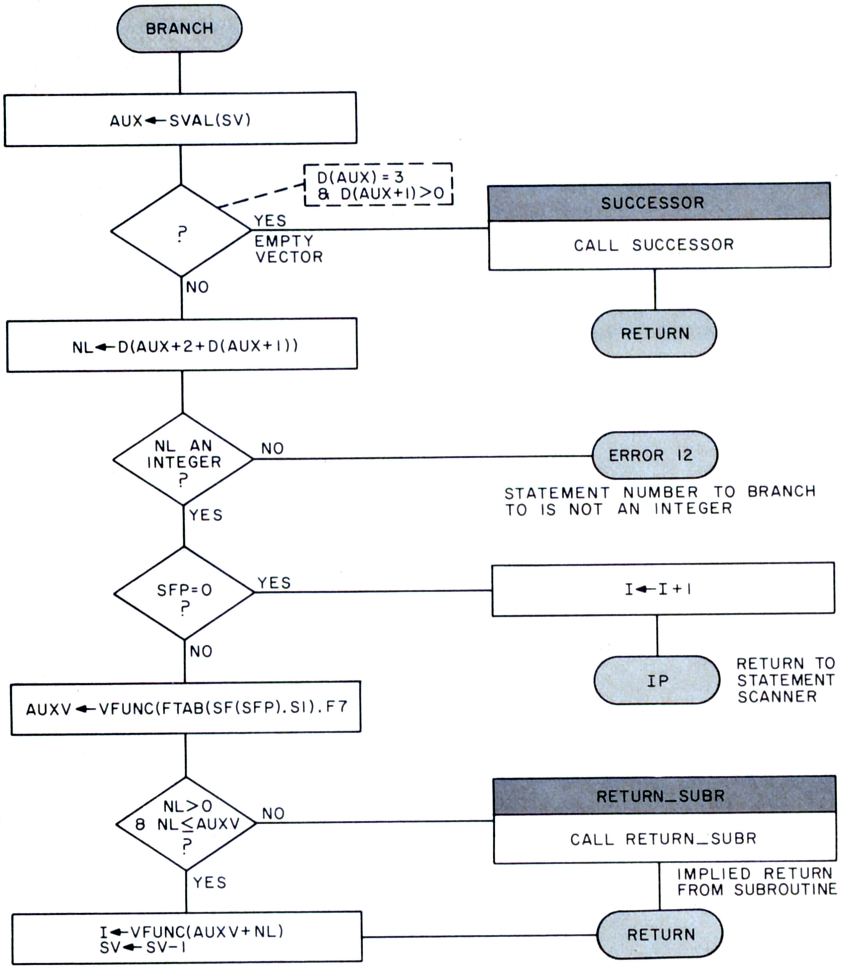

BRANCH
AUX←SVAL(SV)
D(AUX) = 3
& D(AUX+1)>0
?
YES
EMPTY VECTOR
NO
SUCCESSOR
CALL SUCCESSOR
RETURN
NL←D(AUX+2+D(AUX+1))
NL AN INTEGER ?
NO
ERROR 12
STATEMENT NUMBER TO BRANCH TO IS NOT AN INTEGER
YES
SFP=0 ?
YES
I←I+1
IP
RETURN TO STATEMENT SCANNER
NO
AUXV←VFUNC(FTAB(SF(SFP).SI).F7
NL>0
& NL≤AUXV
?
NO
RETURN_SUBR
CALL RETURN_SUBR
IMPLIED RETURN FROM SUBROUTINE
YES
I←VFUNC(AUXV+NL)
SV←SV−1
RETURN

Figure 12: The logic for interpretation of a program branch, ie: a right arrow followed by an expression. A pointer to the result of that expression is in the top of stack SVAL. The result must be an integer equal to the statement number of the desired statement to be executed in the current subroutine. If the result is an empty vector, then the branch is simply to the next statement. A noninteger result is an error. An attempt to branch while not in a subroutine is ignored and control is returned to the statement scanner. Finally, a branch to a statement number not in the current subroutine results in a return from the subroutine.

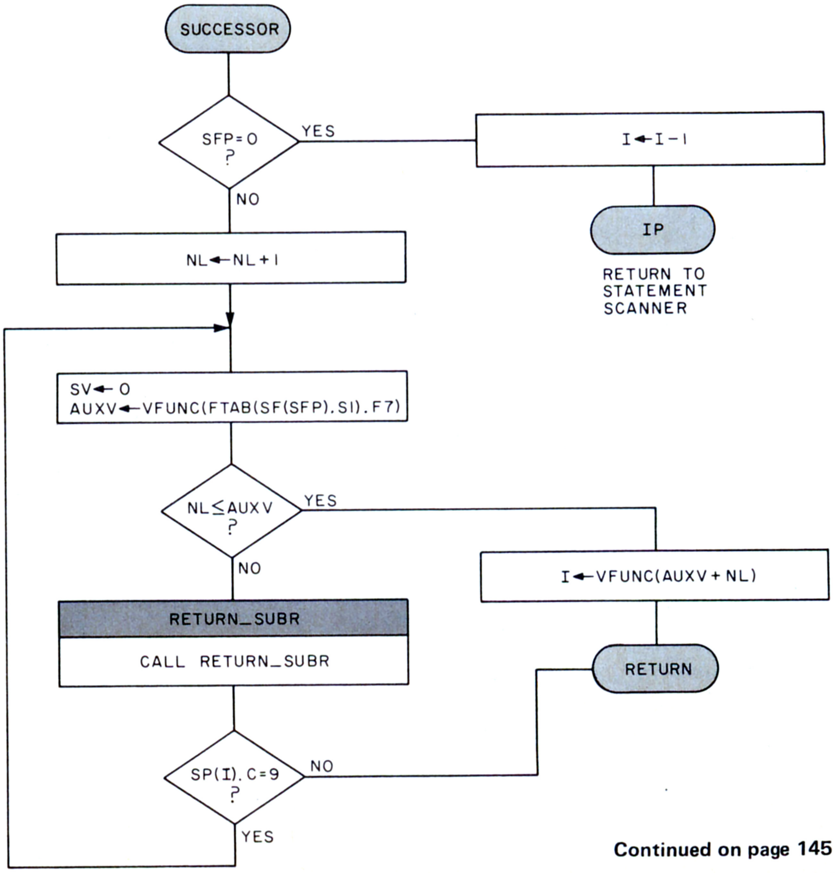

SUCCESSOR
SFP=0 ?
YES
I←I−1
IP
RETURN TO STATEMENT SCANNER
NO
NL←NL+1
SV←0
AUXV←VFUNC(FTAB(SF(SFP).SI).F7)
NL≤AUXV ?
YES
I←VFUNC(AUXV+NL)
RETURN
NO
RETURN_SUBR
CALL RETURN_SUBR
SP(I).C=9 ?
NO
YES

Figure 13. The method for advancing to the next statement function. If there is no next statement while in a subroutine an automatic return from subroutine occurs. At completion of interpretation for the immediate mode statement control is returned to the statement scanner. Otherwise variable I is set to point to the rightmost syllable of the next statement to be interpreted.

Continued on page 145

Introducing HEATHKIT® COMPUTERS

A new value standard in personal computing systems featuring two powerful computers with better software, full documentation and service support from the Heath Company.

Heath Company has been interested and involved with personal computing since we first marketed an analog computer system all the way back in 1957. This continuing interest, along with the recent technological advances that have brought personal computing to the forefront of the electronics marketplace, has given us the opportunity to think through the recent developments, and develop two "total design" computer systems that give the computer hobbyist, whether beginner or advanced, everything needed for REAL power, performance and reliability — at prices that give you MORE value and performance for your computer dollar!

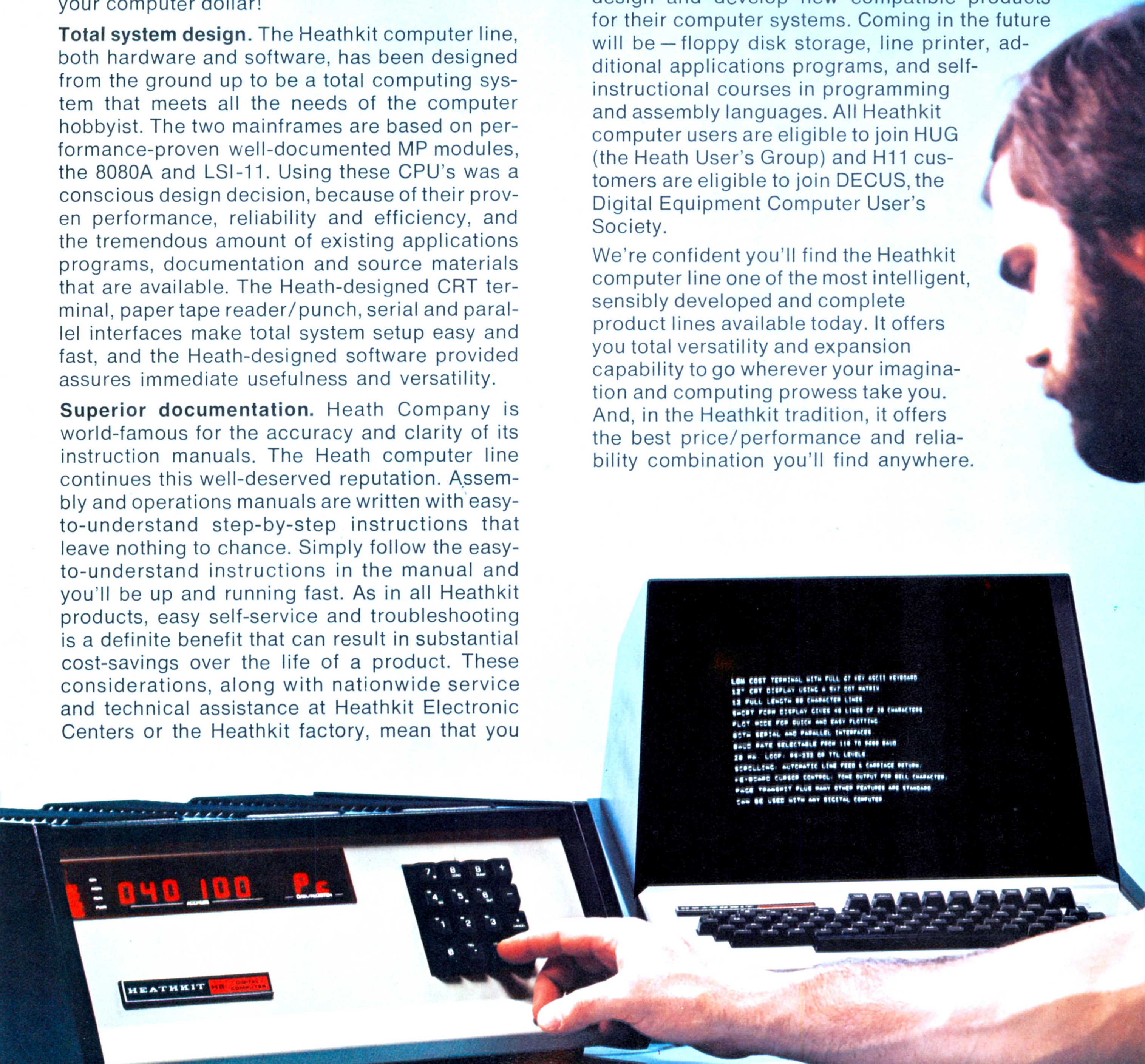
Total system design. The Heathkit computer line, both hardware and software, has been designed from the ground up to be a total computing system that meets all the needs of the computer hobbyist. The two mainframes are based on performance-proven well-documented MP modules, the 8080A and LSI-11. Using these CPU's was a conscious design decision, because of their proven performance, reliability and efficiency, and the tremendous amount of existing applications programs, documentation and source materials that are available. The Heath-designed CRT terminal, paper tape reader/punch, serial and parallel interfaces make total system setup easy and fast, and the Heath-designed software provided assures immediate usefulness and versatility.

Superior documentation. Heath Company is world-famous for the accuracy and clarity of its instruction manuals. The Heath computer line continues this well-deserved reputation. Assembly and operations manuals are written with easy-to-understand step-by-step instructions that leave nothing to chance. Simply follow the easy-to-understand instructions in the manual and you'll be up and running fast. As in all Heathkit products, easy self-service and troubleshooting is a definite benefit that can result in substantial cost-savings over the life of a product. These considerations, along with nationwide service and technical assistance at Heathkit Electronic Centers or the Heathkit factory, mean that you have the most reliable protection for your computer investment available anywhere.

System versatility. Both Heathkit computers offer full expansion potential to provide outstanding flexibility and adaptability to meet any application. Mass storage capability is available in both audio cassette and paper tape format on the H8 and in paper tape format on the H11 for added convenience. Additional memory expansion boards can be added to either unit, along with an expanding number of I/O devices.

Continuing Development. Heath will continue to design and develop new compatible products for their computer systems. Coming in the future will be — floppy disk storage, line printer, additional applications programs, and self-instructional courses in programming and assembly languages. All Heathkit computer users are eligible to join HUG (the Heath User's Group) and H11 customers are eligible to join DECUS, the Digital Equipment Computer User's Society.

We're confident you'll find the Heathkit computer line one of the most intelligent, sensibly developed and complete product lines available today. It offers you total versatility and expansion capability to go wherever your imagination and computing prowess take you. And, in the Heathkit tradition, it offers the best price/performance and reliability combination you'll find anywhere.



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LOW COST TERMINAL WITH FULL 67 KEY ASCII KEYBOARD
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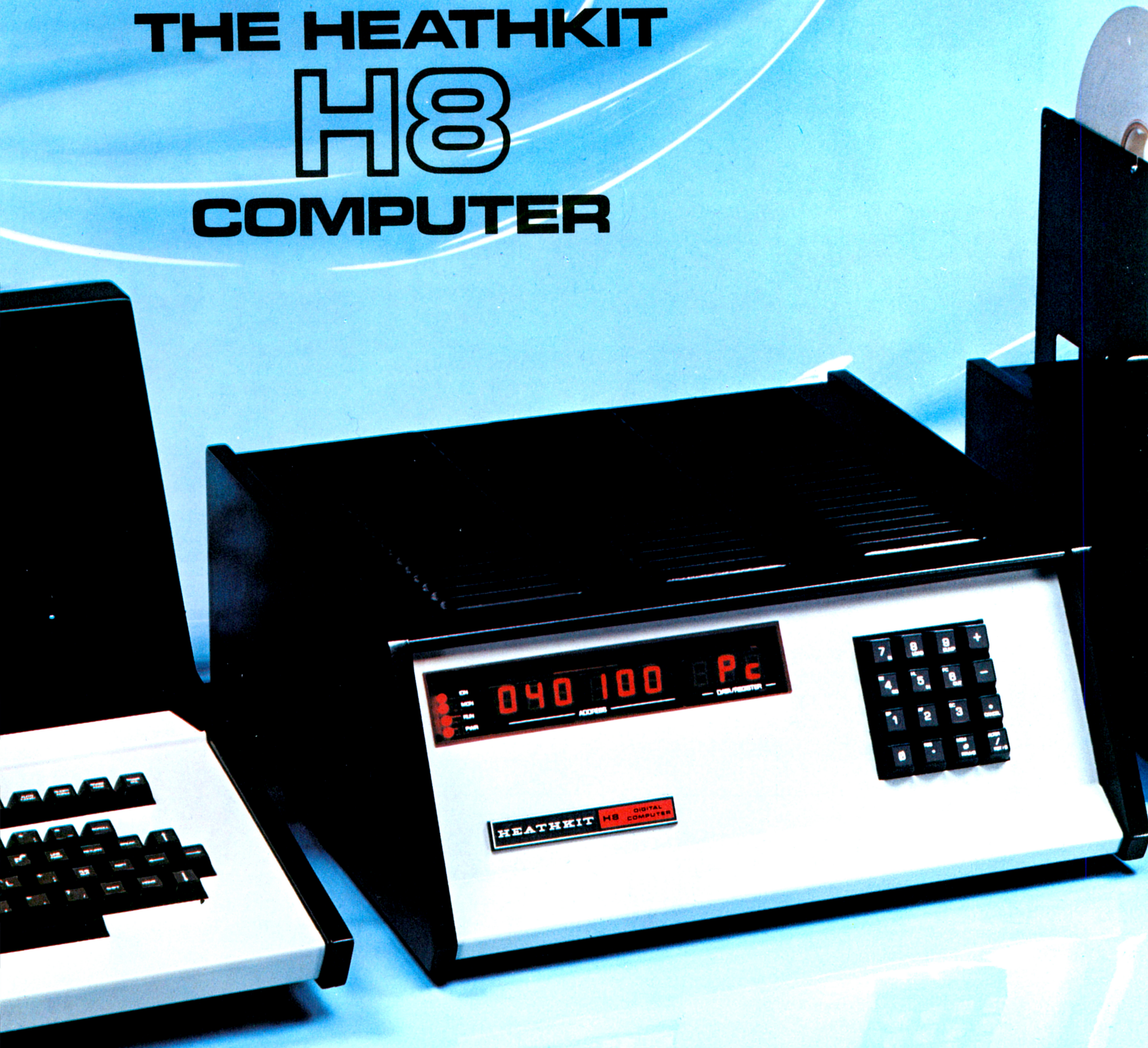
THE HEATHKIT
H8
COMPUTER


040 100 Pc
ADDRESS
DATA/REGISTER
HEATHKIT H8 DIGITAL COMPUTER

A unique, value-packed computer featuring an "intelligent" front panel with built-in extended ROM monitor, octal entry keypad and digital readout, exclusive Heath bus, a pre-wired and tested 8080A-based CPU, and complete systems software at no extra cost!

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HEATH charg-a-kit REVOLVING CHARGE

HEATHKIT 8-BIT DIGITAL COMPUTER

A low-cost digital computer that's easier to build and to use! Features an intelligent front panel with keyboard entry and 9-digit display, a heavy-duty power supply with enough extra capacity for memory and I/O expansion and a 50-line fully buffered bus capable of addressing 65K bytes and a mother board with positions for up to 10 plug-in circuit boards. Includes BASIC, assembler, editor and debug software at no extra cost!

The Heathkit H8 computer is an 8-bit machine based on the popular 8080A chip. It is one of the lowest-cost general-purpose computers on the market, and thanks to Heath's exclusive design, one of the most versatile.

The interrupt controlled "intelligent" front panel gives you far more power and control than is found on conventional units with bit switches and indicators. The 16-digit keyboard allows octal data entry and control that's far faster and less error prone than binary switches. The 9-digit octal readout provides you with more information than conventional models too.

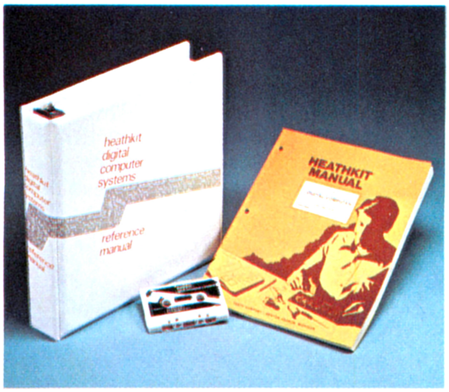
The octal keyboard and display emulate a true hardware front panel with complete access to memory, all registers and functions. The 9-digit seven-segment octal display has three readout modes: 6 digits of address and 3 digits data; 6 digits register data and 2 digits register identification; and three digits data with three digits port address. The front panel functions are defined by a panel monitor control program (PAM-8) stored in a 1K x 8 ROM on the CPU board. The complete access to 8080 internal circuits and functions makes the H8 an ideal trainer and learning tool.

Complete front panel functions include: display and alter of memory locations; display and alter of registers; dynamic monitoring of registers or memory during program execution; program execution control including break-point capability and single instruction step; automatic tape load and store through a built-in routine that allows programs to be loaded with a single button; and write or read any I/O port. The front panel of the H8 is so versatile it's like having a mini I/O terminal built right in!

Other features of the H8 front panel include status lights for power-on, run, monitor and interrupt enable; a built-in speaker for audible feedback on keyboard entry. The speaker also can be programmed for variable tones, permitting a variety of special effects to be generated.

The CPU board is fully wired and tested. It features the 8080A, clock, systems controller, ROM monitor and full bus buffering. Seven vectored interrupts are available on the bus for quick response to your I/O requests. A built-in clock lets you design and run in real time.

The H8 uses an exclusive, Heath-designed bus which incorporates many practical improvements over existing busses. The bus is fully buffered to reduce noise and crosstalk and is "glitch" free to eliminate timing problems. Three-state line drivers and receivers are used on all bus lines to eliminate loading problems. The 50 lines include address, data, control, clock and interrupt lines, plus all signals needed to support the 8080 MPU and virtually any I/O or memory accessory. The bus is implemented on a heavy-duty printed circuit mother board with wide, heavy copper foils for greater physical strength plus reduced crosstalk and noise. The board has 10 positions for installing connectors that accept the front panel, CPU, memory, I/O and accessory cards. All I/O bus connectors are included with the mother board for fast and easy expansion when you want it.

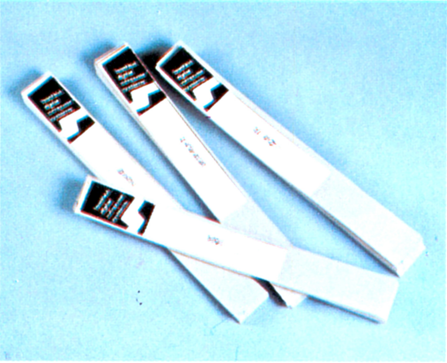


Comprehensive Heathkit assembly and operations manuals give you the superior documentation you NEED for a thorough understanding of your H8.

Systems software is supplied in audio cassette format.

The H8's built-in power supply is convection cooled for adequate ventilation without the use of noisy fans. Separate IC regulators provide distributed regulation with a heat sink on each circuit board for excellent heat dissipation. Power supplies of +8, −18 and +18 volts are provided to handle up to 32k memory plus three I/O interfaces. Switch-selectable 120 V, 60 Hz or 240 V, 50 Hz AC increases versatility.

The H8 includes all system software in 1200 baud audio cassette form at no extra charge. The Benton Harbor BASIC™ is an enhanced version of standard Dartmouth BASIC with unique statements and commands to extend usefulness. The efficient compression techniques of the Benton Harbor BASIC permit you to put more program in less space.



All H8 systems software is supplied in audio cassette form. Also available in paper tape (H8-15, page 5) at extra cost.

HASL-8 The Heathkit Assembly language is a 2-pass absolute assembler that lets you program with easily understood mnemonics and generates efficient machine language code. A minimum of 8K memory is required.

The TED-8 software is a line-oriented text editor used for generating source programs for the assembler or general word processing. Requires a minimum of 8K memory.

The BUG-8 a powerful terminal console debug program, is an enhanced and extended version of the front panel monitor program to allow entry and debugging of user machine language programs via an external terminal. Requires 3K memory plus user program.

The H8 is housed in a rugged, heavy-duty cabinet, 16¼" W x 6½" H x 17" D. Requires at least one H8-1 Memory.

Kit H8, Shpg. wt. 30 lbs. **375.00**

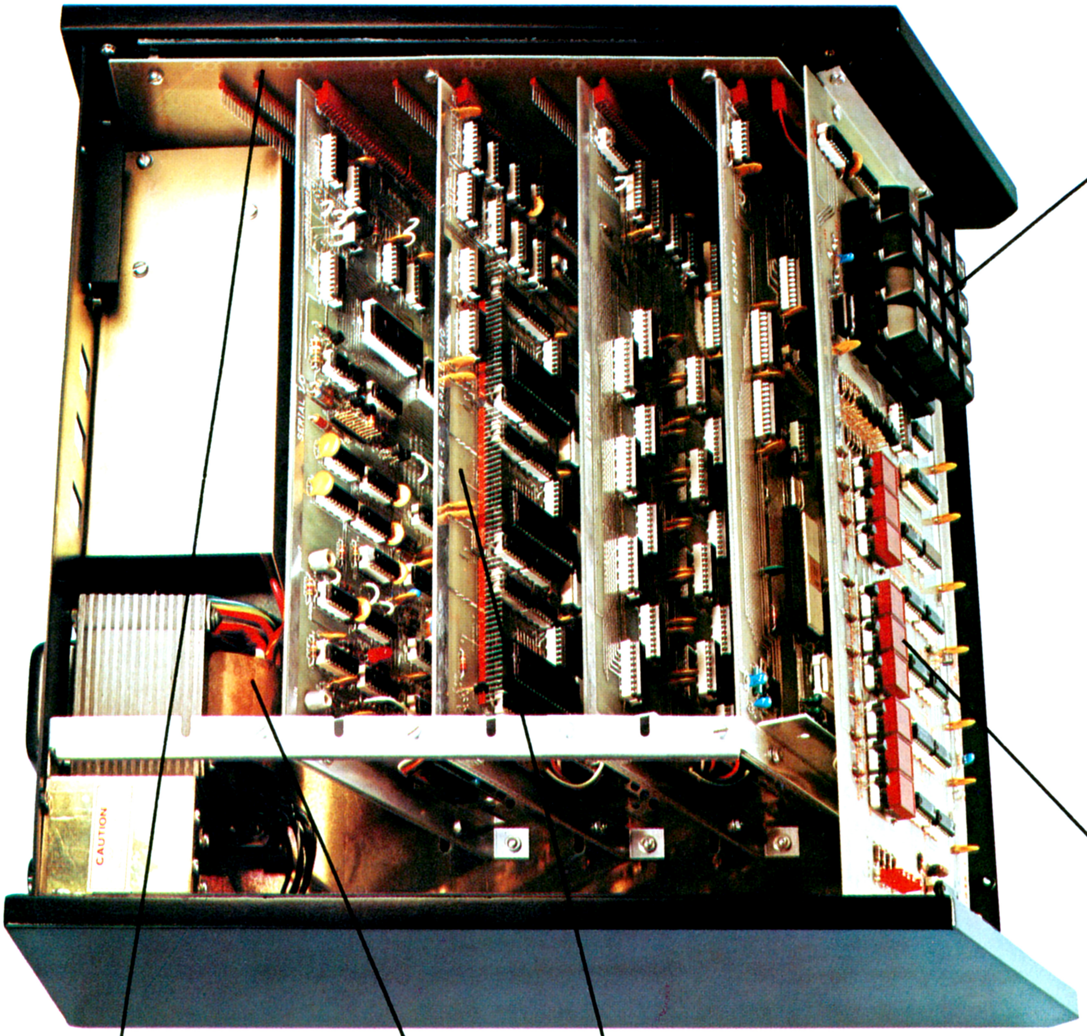
Suggested applications for the H8 computer: As a trainer—learn microprocessor operation, interfacing and programming. The powerful front panel lets you get at and use all parts of the unit.

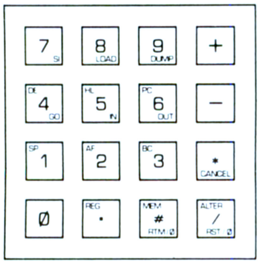
As an entertainment center—use game and other applications programs for entertainment the whole family can enjoy.

As a hobby computer—the H8 can be used to process any information you program into it—it's perfect for hobby experimentation and design. A variety of peripherals and interfaces let you use it with other equipment—run your Ham radio station, control your model railroad systems, etc.

As an educational system—the H8 is ideal for schools, community colleges, libraries, etc. Full H8 software permits teaching BASIC plus machine and assembly language programming.

As a home management center—use the H8 to keep telephone numbers, monitor your budget, keep your checkbook balanced, do your income taxes, inventory your personal belongings. There are hundreds of ways the H8 can make your life more convenient.





Its unique front panel keyboard makes the H8 the most powerful and sophisticated low-cost general-purpose computer available. Just take a look at these features!

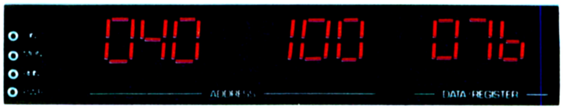
- Direct-access to registers and memory even while program is running
- One button load and dump for fast, uncomplicated system startup
- Single instruction key lets you "step" through programs for easy debugging, program evaluation and learning
- Input/output keys let you communicate directly with any port

The unique Heath-designed 50-pin bus is implemented on a heavy-duty printed circuit board with heavy copper-foil bus lines. The 10-position mother board is complete with all connectors. The bus lines are fully buffered to eliminate noise and crosstalk, and "glitch-free" to prevent timing problems.

Modular circuit boards slide into the H8 mainframe for easy memory and I/O expansion, easy access for servicing. The boards are in a semi-vertical position with unconfined heat sinks to enhance convection cooling and improve heat dissipation.

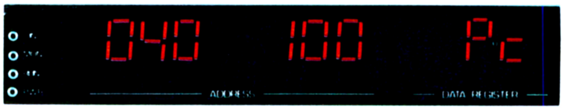
Heavy-duty power supply, rugged steel chassis and securely mounted and braced circuit boards make the H8 a truly reliable and long-life machine.

Memory Display



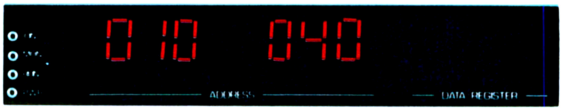
High Order Address Location — Low Order Address Location — Data at Location 040 100

Register Display



High Order Contents — Low Order Contents — Register Identification

I/O Port Display



Data — Port Number

Unique Heathkit Software.

The Heathkit software supplied with the H8 computer has a number of features that make it easier to use and more practical than conventional systems. Automatic "command completion" simplifies typing; dynamic syntax checking instantly alerts you to errors and a special user configuration lets you really personalize your system. H8 software pushes the state-of-the-art a generation ahead — it's memory efficient to give you more computing power for your memory dollar, modular design for easy expansion, and thoroughly documented for easy programming and maximum effectiveness.

H8 "Intelligent" Front Panel

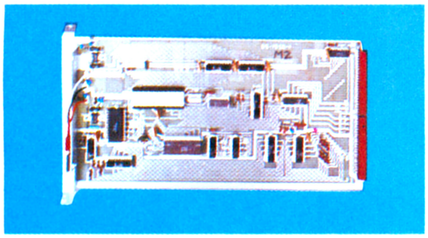
The H8 front panel digital readout is the most informative display available on any personal computer to date. All displays are continuously updated even while your program is executing, giving you instant access to registers and memory for direct monitoring of program activity.

MEMORY DISPLAY — Shows memory location and contents using 6 digits for address and 3 digits for data.

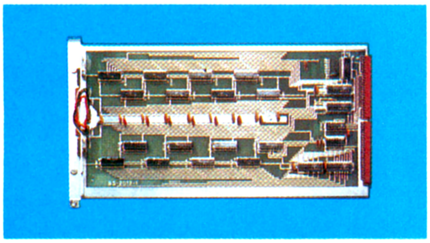
REGISTER DISPLAY — Shows CPU-register contents using 6 digits for data and 2 digits for register identification.

I/O PORT DISPLAY — Shows I/O port data and location using 3 digits for data and 3 digits for port address.

H8 ACCESSORIES, SOFTWARE AND MANUAL SET



The H8 CPU is fully wired and tested to insure quick and trouble-free system startup. It contains the performance proven 8080A microprocessor chip, a 1Kx8 ROM with monitor program for controlling the front panel and input-output (load-dump) routines. Other features of the CPU include: 7 vectored interrupts, DMA capability, crystal-controlled clock and fully buffered bus with three state drivers. Use of the 8080A, which has the largest software library of any microprocessor, along with Heath software and documentation, makes the H8 one of the most practical and immediately useful computers you can own.

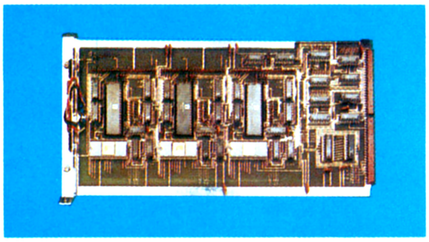


H8-1 Memory Board. 8Kx8 memory card supplied with 4K memory, plugs directly into H8 bus. Features maximum storage capacity of 8192 8-bit words. Uses modern 4Kx1 static memory IC chips for easy assembly and service. Access time, less than 450 nS. With on-board regulators, heat sinks and full buffering. Expandable to 8K memory with H8-3 chip set below.

Kit H8-1, Shpg. wt. 2 lbs. **140.00**

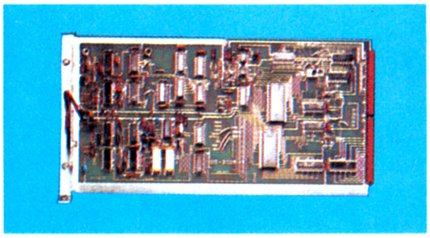
H8-3 Chip Set. Kit of eight 4K static memory IC's. Expands H8-1 to full 8K storage. With sockets.

Kit H8-3, Shpg. wt. 1 lb. **95.00**



H8-2 Parallel Interface. Connects H8 to any parallel device such as a paper tape reader/punch (required for H10) or line printer. Has three independent parallel ports, each with 8 bits input and 8 bits output and universal handshaking capability. Compatible with all Heath software. 390 μS maximum transfer time. With diode-clamped inputs, buffered outputs and full interrupt capability.

Kit H8-2, Shpg. wt. 3 lbs. **150.00**



H8-5 Serial I/O and Cassette Interface. Connects the H8 to serial devices such as the H9 video terminal (page 10) or the H36 DEC Writer II (page 12). Features jumper selectable data rate from 110 to 9600 baud, plus common input/output interfaces including 20 mA current loop and EIA RS-232C compatible levels. The cassette recorder interface permits the use of standard cassette recorders (Heathkit ECP-3801, page 12). Uses the popular Byte/Manchester or "Kansas City" standard recording format with a 300 or 1200 baud read/record rate. Control lines for remote start and stop of two cassette units allow separate record and playback for easy program or file editing. Also has full interrupt capability. LED test circuit for easy board setup and overall system servicing. Fully compatible with all Heath software.

Kit H8-5, Shpg. wt. 3 lbs. **110.00**

NOTE: Proper operation of the H8-5 is assured only if you use the Heath ECP-3801 cassette player/recorder and Heath-recommended recording tape (ECP-3802, page 12). Heath is not responsible for improper operation associated with other cassette units.

Extended Benton Harbor BASIC

Extended Benton Harbor BASIC is an enhanced and more powerful version of the BASIC supplied with the H8. It provides even faster operation and includes character strings, additional convenience commands and math functions, dynamic storage allocation, access to real time clock, keyboard interrupt processing, expanded error messages and recovery ability, LED display control and key pad support. A minimum of 12K memory is required to run this BASIC, 16K is preferred if full use is to be made of its capabilities.

H8-13 (1200 baud audio cassette)
Shpg. wt. 1 lb. **10.00**

H8-14 (fan fold paper tape)
Shpg. wt. 1 lb. **10.00**

Paper Tape Systems Software

A paper tape version of the systems software supplied with the H8 computer. It consists of four fan fold paper tapes, one each for Benton Harbor BASIC, HASL-8 assembler, TED-8 editor, and BUG-8 debug. For use with the H10 paper tape reader/punch or other paper tape I/O equipment.

H8-15, Shpg. wt. 1 lb. **20.00**

H8 Manual Set

Find out about the H8 before you buy! This manual set includes the complete assembly and operations manuals for the H8 Digital Computer, H8-1 memory card, H8-2 parallel interface, H8-3 4K memory expansion chip set, H8-5 serial and I/O cassette interface, H9 video terminal and H10 paper tape reader/punch. H8 software documentation covering monitor, editor, assembler, debug and BASIC is also included. In handsome 3-ring binder.

HM-800 Manual Set.
Shpg. wt. 11 lbs. **25.00**

The purchase price of the HM-800 manual set will be refunded when you buy the H8. Simply include HM-800 saleslip with your order.

HEATHKIT MANUAL
HEATHKIT MANUAL
HEATHKIT MANUAL

Heath
User's
Group

You can get even more excitement and practical use from your H8 by joining HUG, the Heathkit User's Group. It will put you in contact with other Heathkit computer users, provide a program library and an informative newsletter to keep you up to date. A HUG application is enclosed with each Heathkit computer product. See page 12 for further details.

THE HEATHKIT
H11
DIGITAL COMPUTER

Two of the finest names in modern electronics, Heath and Digital Equipment Corporation (DEC) combine to bring you the world's first 16-bit computer priced within reach of the general public!

$1295.00

DC ON
RUN
DC OFF
HALT
HEATHKIT H11 DIGITAL COMPUTER
digital LSI-11

HEATH charg-a-kit REVOLVING CHARGE

The H11 and all its accessories will be available November 10th, 1977.

HEATHKIT®/DIGITAL EQUIPMENT CORPORATION®
H11 DIGITAL COMPUTER

Heath and DEC join forces to bring you mini-computer performance at a microcomputer price! The H11 features a fully wired and tested DEC KD11F board that contains the 16-bit LSI-11 CPU, 4096 x 16 read/write MOS semiconductor memory, DMA operation; and includes the powerful PDP-11/40 instruction set, PLUS Heath/DEC PDP-11 software. Equivalent commercial versions of the H11 would cost $1,000's of dollars more!

The new Heath/DEC H11 personal computer is one of the most powerful and sophisticated units available today! It combines the advanced, performance-proven hardware and software of the LSI-11 with Heath's expertise in kit design and documentation to bring you a personal computer of almost incredible power and flexibility. Equivalent commercial versions of the H11 would cost over twice as much, and you still wouldn't get the superior documentation and support of the H11!

The LSI-11 bus is a mechanically and electrically superior bus with 38 high-speed lines containing data, address, control and synchronization lines. Sixteen lines are used for time multiplexing of data and addresses. All data and control lines are bidirectional, asynchronous, open-collector lines capable of providing a maximum parallel data transfer rate of 833K words per second under direct memory access operation.

The 16-bit CPU functions are contained on four MOS LSI integrated circuit chips. These chips provide all instructions, decoding, bus control, and ALU functions of the processor. The CPU has eight general registers which serve as accumulators, index, autoincrement/autodecrement registers or stack pointer.

The KD11F memory is a 4096-by-16 MOS semiconductor memory composed of LSI 4K dynamic RAM chips. These chips require little power, provide fast access time, and are refreshed automatically by the processor's microcode. Additional memory cards can be added to expand memory capacity up to 20K in the H11 cabinet (32K words total).

The backplane/card guide assembly holds the microcomputer and up to six I/O and memory modules. All LSI-11 bus data, control, and power connections are routed on the printed circuit backplane to each module location. The backplane/card guides are fully compatible with all standard DEC LSI-11 accessories.

An efficient, well-designed switching power supply provides the required DC voltage for the LSI-11 as well as all accessory modules. The supply features overvoltage and overcurrent/short-circuit protection, power fail/automatic restart and a built-in fan for quiet cooling. The dual primary power configuration can be connected for 115 V, 60 Hz or 230 V, 50 Hz input power.

Has single-level, vectored, automatic priority interrupt, real-time clock input signal line, ODT/ASCII console routine/bootstrap resident in microcode for automatic entry into debugging mode, replacement of panel lights and switches with any terminal device generating standard ASCII code, and the ability to automatically commence operation through resident bootstrap routines.

The H11 is supplied with versatile PDP-11 software including editor, relocatable assembler, linker, absolute loader, debug program, I/O executive program, dump routines, BASIC and FOCAL (See details below). The software requires a minimum of 8K memory, with 12K to 16K total memory recommended for maximum capability. Rugged metal cabinet measures 6½" H x 19" W x 17" D. For 110/220 VAC, 50/60 Hz.

Kit H11, Shpg. wt. 34 lbs. **1295.00**
NOTE: See DEC software license form on page 15.

POWERFUL HEATH/DEC PDP-11 SOFTWARE AT NO EXTRA COST!

The H11 includes a sophisticated software system that lets you get your computer up and running with practical programming capabilities. This paper tape based software would cost over $1200 if purchased separately. A minimum of 8K memory is required to run the software. The programs include:

ED-11. Assists you in the creation and modification of ASCII source tapes, also used to write assembly language programs and for general text editing or word processing functions.

PAL-11S. Relocatable assembler converts ASCII source tapes into relocatable binary modules. This lets you create programs in small, modular segments for easier coding and debugging. These binary modules serve as inputs to LINK-11S.

LINK-11S. Link editor which links the modules created by the PAL-11S into a load module ready for execution on the H-11. The module is loaded into the H-11 via the Absolute Loader.

heathkit digital computer systems reference manual
HEATHKIT MANUAL

The H11 is complete with superior Heathkit documentation and versatile system software.

Absolute Loader. Loads absolute binary tapes into the H11 memory for execution.

ODT-11X. Lets you debug the programs which you have created. Permits modifying and controlling program execution "on the fly" for quick, efficient debugging.

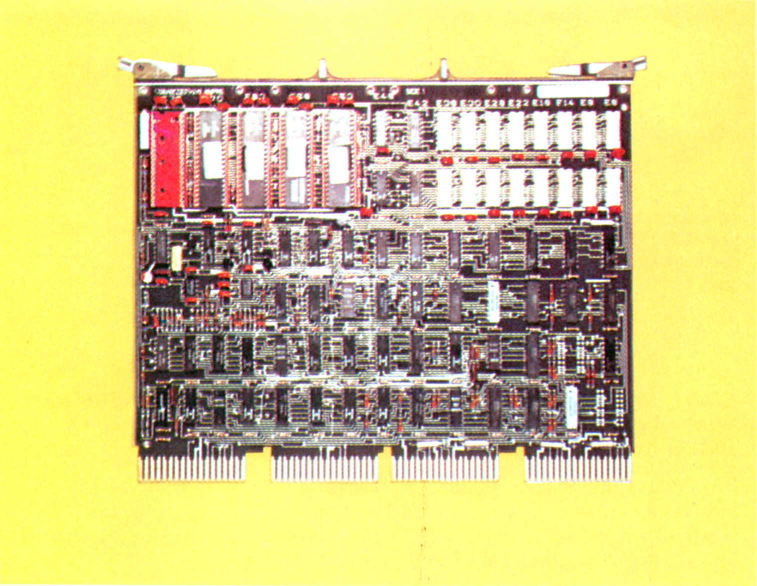
IOX. I/O executive program permits I/O programming without developing device-driving programs. Links to your programs using the LINK-11S. For use with high speed paper tape reader/punch and line printer.

DUMP-AB and DUMP-R. Lets you dump absolute binary contents of memory into the paper tape punch.

BASIC. DEC's powerful version of standard Dartmouth BASIC interpreter uses english-type statements and mathematical symbols to perform operations. Immediately translates, stores and executes the program. Includes string capability.

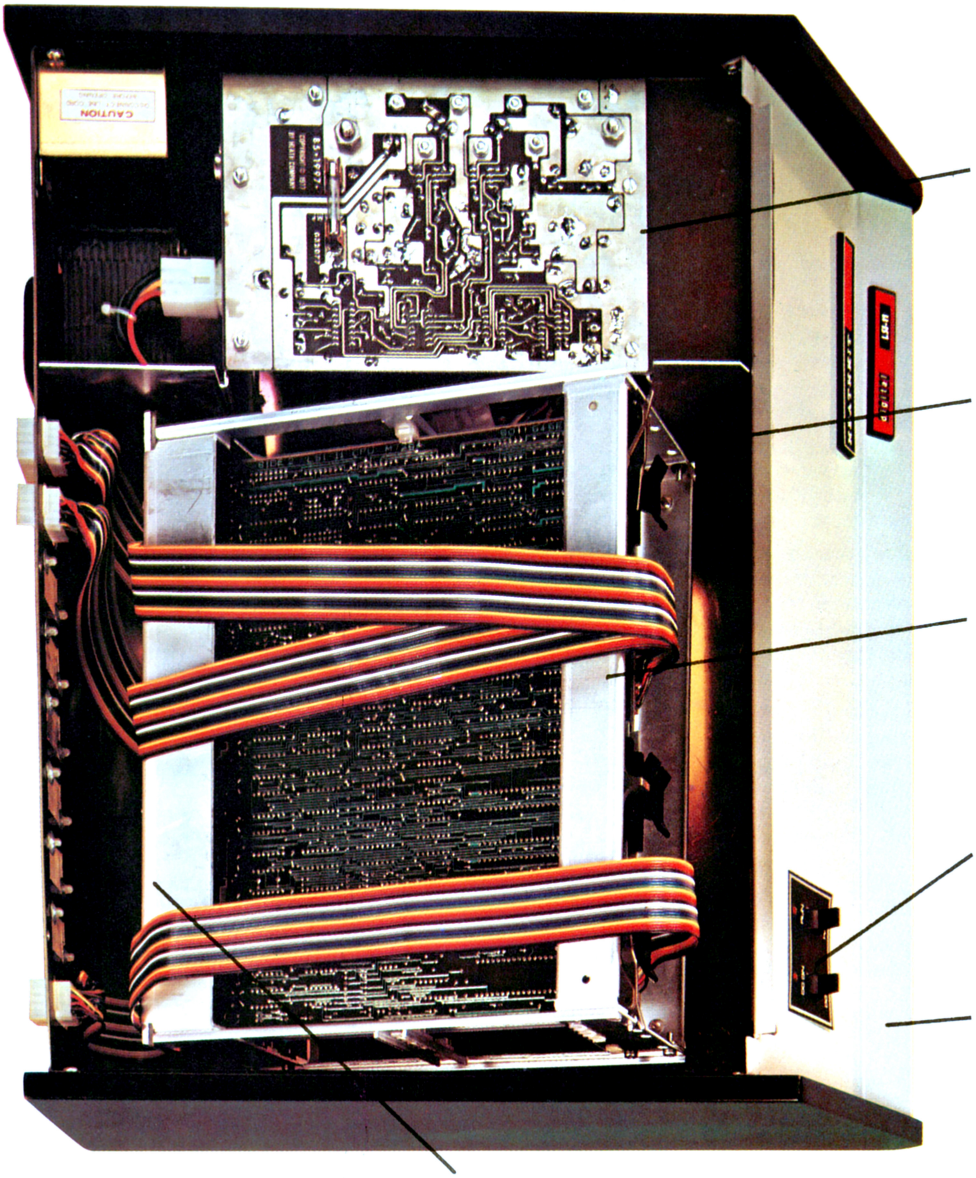
FOCAL™. DEC's own interpretive computer language which combines simplicity with computing power. Ideal for most scientific, engineering and math applications. FOCAL™ programs can be written and executed easily. Both 4K and 8K versions are included.

NOTE: H11 owners are eligible for membership in the Digital Equipment Computer User's Society (DECUS). This organization provides useful symposia, newsletters, program library and other useful information to help you get the most from your LSI-11 computer.



FULLY WIRED AND TESTED KD11F BOARD

The "heart" of the H11 computer is the standard DEC LSI-11 microcomputer board. The 16-bit CPU functions are contained in four silicon gate N-channel MOS LSI integrated circuit chips for high reliability and superior performance. The 4096-by-16 read/write MOS semiconductor memory is composed of LSI 4K dynamic RAM chips that provide fast access time and require little operating power. The CPU executes the powerful PDP-11/40 instruction set with over 400 instructions. There are no separate memory I/O or accumulator instructions, so you can manipulate data in peripheral device registers as easily and flexibly as in memory registers. The LSI-11 board is supplied fully wired and tested to facilitate kit assembly and provide greater reliability and less chance of error.



Compact, efficient switching power supply uses less power to operate and generates less heat than conventional supplies. Overvoltage and overcurrent/short circuit protection, along with automatic power-up and power-down sequencing, provide high reliability and long life operation.

Built-in quiet-running fan provides efficient cooling and prevents heat buildup.

Card cage with backplane accommodates up to six accessory cards in addition to LSI-11. The card cage swings up for easy access and service even while the H11 is operating. Accessory boards slide directly into card guides with all connectors supplied.

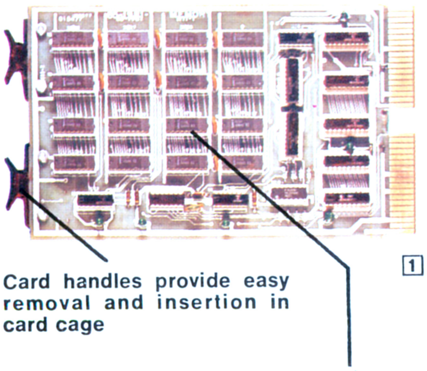
Front panel controls include DC power switch and run/halt switch. Status lights indicate processor activity.

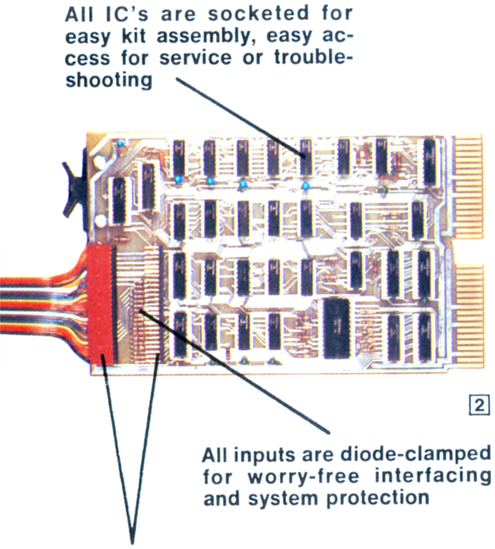
Styled and sized to match Heathkit peripherals for total system continuity.

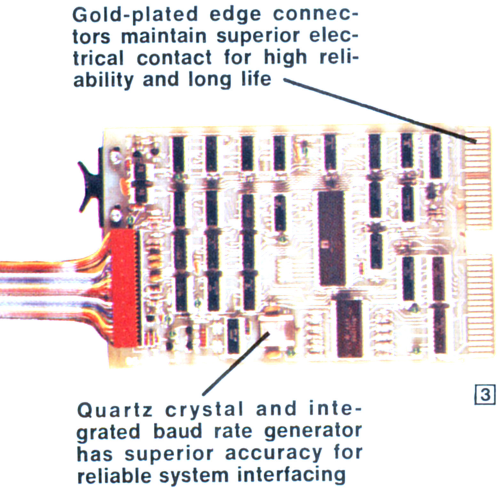
Rugged steel chassis and extra-thick backplane with heavy, solid connectors for added strength and years of superior performance.

The H11 and all its accessories will be available November 10th, 1977.

H11 ACCESSORIES, SOFTWARE AND MANUAL SET


Card handles provide easy removal and insertion in card cage
Sixteen state-of-the-art 4K static memory chips for high density storage
1


All IC's are socketed for easy kit assembly, easy access for service or troubleshooting
2
All inputs are diode-clamped for worry-free interfacing and system protection
Separate cables and rear panel connectors for high-byte and low-byte increase system flexibility


Gold-plated edge connectors maintain superior electrical contact for high reliability and long life
3
Quartz crystal and integrated baud rate generator has superior accuracy for reliable system interfacing

1 H11-1 4K Memory Expansion Module

Plugs into H11 backplane, adds 4K x 16-bit word capacity to H11 memory. Uses high-reliability 1Kx4 static MOS RAM chips. Access time is less than 500 nS. Has decode circuitry for operation on 4K address boundaries. Handle for easy removal and insertion. Compatible with PDP 11/03 and other LSI-11 backplane machines.

Kit H11-1, Shpg. wt. 2 lbs. **275.00**

2 H11-2 Parallel Interface

General-purpose parallel interface featuring 16 diode-clamped latched data input lines, 16 latched output lines, 16-bit word or 8-bit byte data transfers. Has LSI-11 bus interface and control logic for interrupt processing and vectored addressing; control status registers compatible with PDP-11 software routines. Four control lines for output data ready, output data accepted, input data ready and input data accepted logic operations. Maximum data transfer rate, 90K words per second under program control. Maximum drive capability, 25-ft. cable. Plugs into H11 backplane, can be used with DEC PDP-11/03 and other LSI-11 backplane machines. Also compatible with TTL or DTL logic devices. The H11-2 is required for interfacing the H11 to the H10 Paper Tape Reader/Punch.

Kit H11-2, Shpg. wt. 2 lbs. **95.00**

3 H11-5 Serial Interface

Universal asynchronous receiver/transmitter serial interface module for use between LSI-11 bus and serial devices such as the Heathkit H9 video terminal (page 10) or LA36 teleprinter (page 12). Has optically isolated 20 mA current loop and EIA interfaces; selectable baud rates of 50, 75, 110, 134.5, 150, 200, 300, 600, 1200, 1800, 2400, 4800 and 9600. Plugs into H11 backplane, fully compatible with PDP 11/03 and other LSI-11 backplane machines. With all mating connectors.

Kit H11-5, Shpg. wt. 2 lbs. **95.00**

H11-6 Extended Arithmetic Chip

Adds powerful arithmetic instructions to the LSI-11, including fixed point multiply, divide and extended shifts plus full floating point add, subtract, multiply and divide. Helps minimize or eliminate arithmetic sub-routines, speeds up program execution and eases program development. Saves memory space too. 40-pin dual-inline package IC plugs into socket on KD11F board.

H11-6, Shpg. wt. 1 lb. **159.00**

Manual Set for H11 Computer

Includes complete assembly and operation manuals for the H11 Digital Computer, H11-1 4K memory board, H11-2 parallel interface, H11-5 serial interface, H9 CRT terminal, and H10 paper tape reader/punch. Also includes complete software documentation — monitor, editor, assembler, linker, BASIC, FOCAL and related software. In handsome 3-ring binder.

HEATHKIT MANUAL
HEATHKIT MANUAL
HEATHKIT MANUAL

HM-1100 Manual Set,
Shpg. wt. 12 lbs. **25.00**

NOTE: The price of the manual set can be deducted when you order an H11.

NOTE: DEC, DIGITAL, FOCAL and PDP are registered trademarks of Digital Equipment Corporation.

Special DEC Software License Requirement

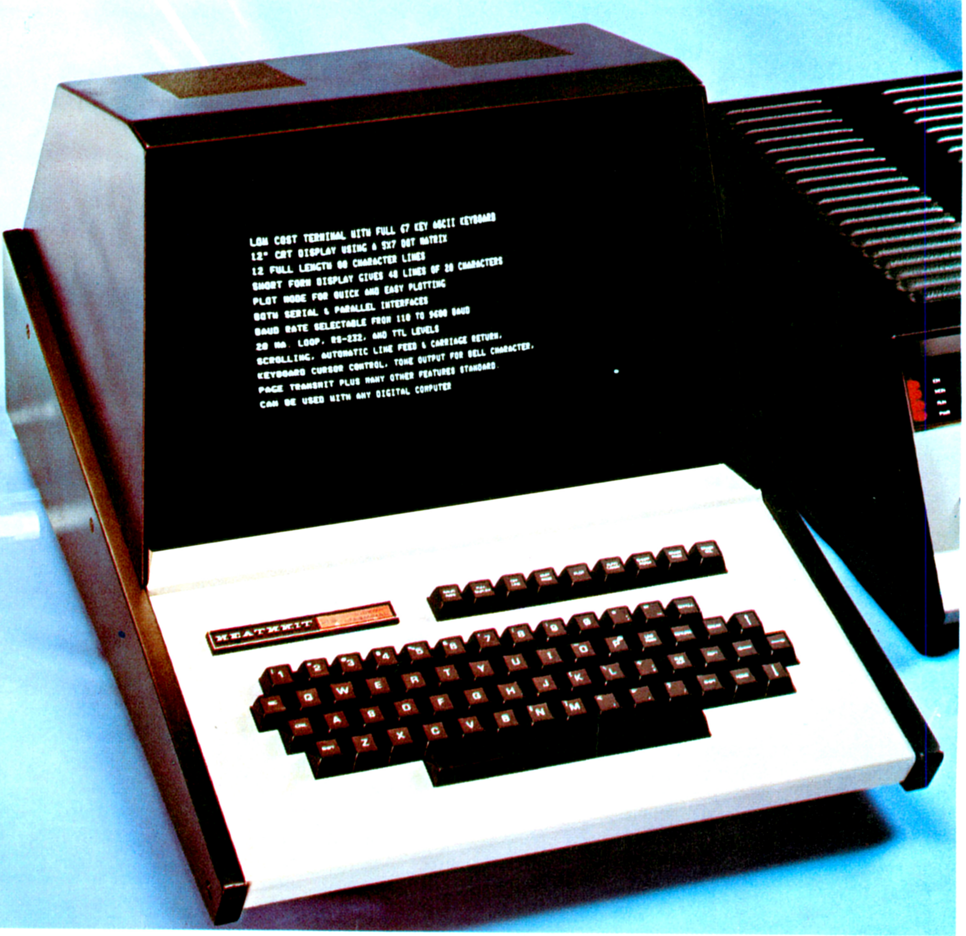
H11 purchasers are required to fill out and sign the DEC license agreement on page 15. Please do so and include with your H11 order. Heath cannot ship merchandise without this license agreement.

THE HEATHKIT H9 VIDEO TERMINAL

One of the lowest-cost full ASCII terminals available anywhere — features a bright 12″ CRT display with twelve 80-character lines, 67-key keyboard, all standard serial interfaces, plus a fully wired and tested control board and a wiring harness for simplified assembly.

$530⁰⁰

HEATH charg-a-kit REVOLVING CHARGE



```
LOW COST TERMINAL WITH FULL 67 KEY ASCII KEYBOARD
12" CRT DISPLAY USING A 5X7 DOT MATRIX
12 FULL LENGTH 80 CHARACTER LINES
SHORT FORM DISPLAY GIVES 48 LINES OF 20 CHARACTERS
PLOT MODE FOR QUICK AND EASY PLOTTING
BOTH SERIAL & PARALLEL INTERFACES
BAUD RATE SELECTABLE FROM 110 TO 9600 BAUD
20 MA. LOOP, RS-232, AND TTL LEVELS
SCROLLING, AUTOMATIC LINE FEED & CARRIAGE RETURN,
KEYBOARD CURSOR CONTROL, TONE OUTPUT FOR BELL CHARACTER,
PAGE TRANSMIT PLUS MANY OTHER FEATURES STANDARD.
CAN BE USED WITH ANY DIGITAL COMPUTER
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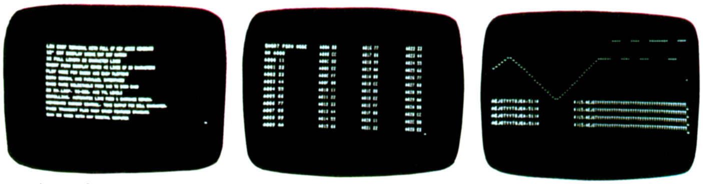
H9 LONG AND SHORT-FORM VIDEO DISPLAY TERMINAL



Long form — twelve 80-character lines

Short form — forty-eight 20-character lines

Plot mode — graphs, curves, simple figures

Three separate modes give the H9 real display versatility

The H9 video terminal is a general-purpose computer peripheral designed for use with the Heathkit H8 or H11 computers. It provides keyboard input and a CRT for the convenient entry and display of computer programs and data. The H9 can be used with any digital computer in dedicated stand-alone applications or in time-sharing systems.

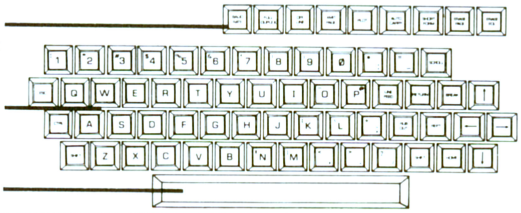
Character format is standard upper case 5 x 7 dot matrix. The long form display is twelve 80-character lines. The short form display is forty-eight 20-character lines in four 12-line columns. The automatic line carryover feature executes line feed and return when line exceeds character count on both long and short form displays. A built-in oscillator/speaker generates a 4800 Hz tone and serves as audible end-of-line warning.

Auto-scrolling is featured in both long and short form. In the long form, as the line enters at bottom, the top line scrolls off-screen; in the short form, as new column enters from right, the left column scrolls off-screen. Auto-scrolling can be defeated with a front panel switch. The cursor mark indicates the next character to be typed for accurate positioning. Cursor control keys include up, down, left, right and home. Serial data baud rates are selectable from 110-9600. Baud rate clock output and reader control are available on the rear panel connector. The erase mode permits automatic full page erase or erase to end of line starting at cursor position. A transmit page function allows a full page to be formatted, edited and modified, then transmitted as a block of continuous data.

The plot mode permits graphs, curves and simple figures to be displayed. Plotting can be accomplished via the keyboard or from external inputs.

Control PC board is fully assembled and tested for added reliability and simplified kit assembly. A wiring harness with connectors helps reduce time-consuming point-to-point wiring.

Full ASCII 67-key Keyboard


Function keys are positioned away from characters to prevent miskeying and error.
Standard typewriter keyboard for easy, more accurate input.
Wide, easy-to-use space bar aids accurate typing.

The H9 serial interface provides EIA RS-232C levels, a 20 mA current loop or standard TTL levels. Parallel interfacing includes standard TTL levels, 8 bits input and 8 bits output and 4 handshaking lines.

Ultra-compact size, only 12½″ H x 15⅝″ W x 20¾″ D, makes the H9 ideal for desktop or console applications. For 110 VAC, 60 Hz or 230 VAC, 50 Hz.

Kit H9, Shpg. wt. 50 lbs. **530.00**

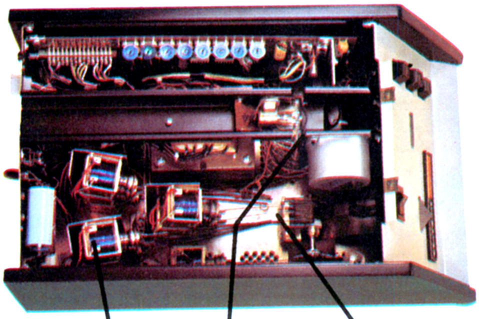
HEATHKIT H11 DIGITAL COMPUTER
HEATHKIT H10 PAPER TAPE SYSTEM
HEATH charg-a-kit REVOLVING CHARGE

THE HEATHKIT H10 PAPER TAPE READER/PUNCH

A general-purpose mass storage peripheral designed for use with the H8 and H11 computers plus any other computer. Features a heavy-duty built-in power supply, totally independent punch and reader and a copy mode for fast, easy tape duplication.

$350⁰⁰

H10 DELUXE PAPER TAPE READER/PUNCH


Heavy-duty solenoids for reliable, long-life operation
Precision machined punch block for accurate, consistent punched holes
Advanced reader design with stepper motor and solid-state sensors for accurate reading

The H10 is a complete paper tape reader/punch mass storage peripheral using reliable low-cost paper tape. It's fully compatible and styled to match with the H8 and H11 computers. It also works reliably with any other computer through a parallel interface. The H10 uses standard 1″ wide roll or fan-fold 8-level paper tape. Standard punched paper tape gives you the reliability, durability and trouble-free handling you need for effective mass storage of programs and data.

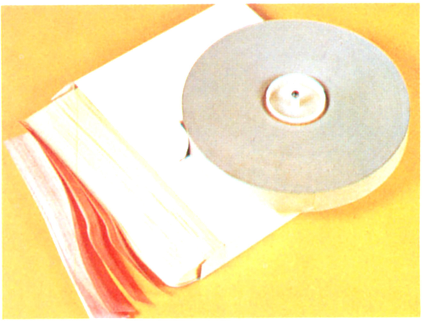
The reader reads tape at a maximum rate of 50 characters per second. A full sensitivity adjustment on each channel permits any color, thickness, quality (oiled or unoiled) paper tape to be used. Sensitive photo Darlington transistors and an incandescent lamp reader head provide reliable reading. The powerful stepper motor drive insures accurate tape positioning and movement.

The punch operates at a maximum speed of 10 characters per second. Precise ratchet/solenoid drive and reliable solenoid control of punches provide high-accuracy punching. The precision die-block punch head gives you positive and consistent punching.

Controls include power on-off, read and punch start. A feed control feeds blank paper tape through the punch to produce leader tape. A copy control on the rear panel permits tape being read to be duplicated by the punch for efficient and accurate tape copying.

Interface has parallel 8-bit input bus for punch, parallel 8-bit output bus for reader, standard TTL logic levels and handshaking lines for both reader and punch. A rear panel 24-pin interface connector and mating cable are supplied. The H10 is fully compatible with Heathkit H8 and H11 computers when the appropriate parallel interface accessories are used. It can also be interfaced with other computers with parallel interface facility.

Accessories include holder for roll paper tape, chad collector tray, and collector box for fan-fold tape. With 8″ roll (900 ft.) blank paper tape.



Styled to match the Heathkit H8 and H11 computers. Cabinet with metal top and rugged steel chassis, 12⅝″ H x 9¾″ W x 19⅝″ D. For 110-130 VAC, 60 Hz, or 220-240 VAC, 50 Hz.

Kit H10, Shpg. wt. 29 lbs. **350.00**

H10-2, Three Blank Rolls Paper Tape, each 8″ diameter, 900 ft. min.

H10-2, Shpg. wt. 5 lbs............**10.00**

H 10-3, Three Boxes Blank Fan-fold Tape. Approx. 1000 ft. each.

H10-3, Shpg. wt. 5 lbs............**10.00**

ECP-3801 Cassette Recorder Storage Device

Has volume and tone controls, pushbuttons for record, play, rewind, fast forward, stop and eject, built-in 3-digit counter with reset button. Factory wired, not a kit.

ECP-3801, Shpg. wt. 6 lbs. **55.00***

Heath recommended high output, low noise, premium grade audio recording tape. Pack of three 30-minute blank cassettes.

ECP-3802, Shpg. wt. 1 lb. . . . . **per pack 5.00**

*NOTE: Proper operation of the H8-5 and H8 software is assured only when the ECP-3801 cassette recorder and ECP-3802 tape is used. Heath does not assume responsibility for improper operation resulting from the use of any other cassette units.

HUG®–the Heathkit User's Group

Our new user's group brings you in contact with other Heathkit computer owners and users, provides a newsletter, a program library, new product information and hardware/software ideas. Membership in HUG is a useful, practical way to get the maximum enjoyment and benefit from your Heathkit computer system. Here's what you get:

- 1 year subscription to the quarterly newsletter
- Software library allowing you to submit programs and obtain programs submitted by others. A modest fee will be charged for software duplication.
- An attractive 3-ring binder to hold newsletters, software documentation and other materials.
- Program submission forms
- Software library catalog
- HUG membership list
- Credit toward purchase of software

Dues are $14.00 for one year. Complete details of HUG membership are included with every Heathkit computer product. H11 owners are also eligible for membership in DECUS, see page 7 for details.

LA36 DEC Writer II Keyboard Printer Terminal

The famous LA36 DEC Writer II with true 30-cps throughput, variable-width forms handling, 128-character upper/lower case set, and extra-quiet operation. Fully assembled, factory tested and ready to use!

The LA36 is an advanced technology teleprinter offering fast, reliable operation at one of the best price/performance ratios in the industry. It features a 7x7 dot matrix print head for crisp, clear character formation; switch-selectable 10, 15 and 30 cps printing speeds; variable width forms handling from 3 to 14⅞" wide; adjustable right and left hand tractors for precise margin positioning; half or full duplex operation; ANSI-standard multikey rollover and a typewriter-like keyboard.

The precision-designed stepper motor paper feed has fine vertical adjustment for accurate forms placement. LA36 will handle up to 6-part forms with a .020" maximum pack thickness. Print format is 132-column, with 10 characters per inch horizontal spacing and 6 lines per inch vertical spacing. Uses the entire 128 character ASCII upper/lower case set with 95 printable characters. A CAPS-lock key simplifies data entry. A parity check on output prints a replacement character, strappable to odd, even, or none with mark or space. A last-character visibility feature moves the head four columns to the right when printing stops, returns to proper position when printing is resumed.

The integral 20 mA current loop interface makes the LA36 compatible with both the H8 and H11 computers, as well as all other hobby and personal computers. Operates on 90-132 VAC or 180-264 VAC for reliable performance even under brown-out conditions. With connecting cable and integral stand for easy setup. Overall size, 27½" W x 33¼" H x 24" D.

H36 (LA36 DEC Writer II) Shipped Motor Freight, prepaid to your nearest terminal within the Continental U.S. Include your phone number on order for notification of arrival. Arrangements for home delivery at extra charge at your option. NO C.O.D ORDERS ACCEPTED. **$1495.00**

H36-1 Fan-fold paper for H36. Standard 14⅞" x 11" white and green, single part, lined paper. 3450 sheets per carton.

H36-1, Shpg. wt. 50 lbs. **30.00**

H36-2 EIA Interface. Provides EIA RS232-C or CCITT-V24 interface for LA36. Includes auto answer, timed disconnect and half/full duplex logic. Straps are available to send timed break (230 mS), 3000 mS long space, forced disconnect or do nothing (stops printing, discards data) on a paper-out condition. Modem controls and a 9-ft. cable with 25-pin data-set type connector are also supplied. Factory wired, not a kit.

H36-2. Shpg. wt. 1 lb. **65.00**

APPLICATIONS SOFTWARE–COMING SOON!

Both the H8 and H11 Digital Computers are supplied with complete systems software that provide you with everything you need to develop your own specific applications programs. However, you can make your computer immediately useful by using the programs below. These programs represent the beginning of a complete series of application software packages that will allow you to get immediate value from your computer system without a time consuming software development effort on your part. Described below are a series of game packages that make your computer an excellent source of entertainment and leisure time activities.

BLACKJACK. An interactive program game that allows four players to play the card game blackjack on the computer. The computer performs all of the functions of the dealer and keeps track of player progress, winnings and losses. The program is written in and runs under extended BASIC and requires a minimum of 16K of RAM in the H8 and 8K in the H11. Standard Las Vegas casino blackjack rules apply.

BIORHYTHM. This popular applications program computes standard biorhythm information and plots sinusoidal curves of your physical, emotional, and intellectual characteristics over a given time period. The biorhythm program will show you your ups and downs and will tell you your good and bad days. It will help you plan your activities. While this program is not a game, it is an entertaining activity that you and your friends and family will enjoy. The program runs under extended BASIC and requires 16K of RAM in the H8 and 12K RAM in the H11.

STARTREK. Startrek is perhaps the most popular computer game available. It allows you to guide, control and command the Starship Enterprise in its travels through the galaxy, fighting Klingons and solving a variety of problems. A truly challenging, sophisticated and entertaining computer game. Runs on the H8 or H11 computers with 8K of RAM or more.

GAME SET #1. This software package lets you play 8 popular computer games. These games include Craps, Orbit, Tic Tac Toe, Nim, Hexapawn, Hangman, Hmrabi, and Derby. 8K RAM or more is required on either the H8 or H11. These games will provide hours of entertainment for you and your family.

GAME SET #2. Another popular game package for the H8 and H11 computers. Contains 8 popular computer games including bagles, slot machine, gomoko, yahtze, apollo, gunner, wumpus, and cube.

AVAILABILITY. Blackjack, Biorhythm and Startrek will be available after October, 1977. Game Set #1 will be available November, 1977 and Game Set #2 available, February, 1978.

Order a complete Heathkit computer system and SAVE!

The ECP-3801 is the Heath-recommended cassette recorder/player for use with the H8 computer software. See opposite page for complete description.

SYSTEM ONE

The minimum recommended H8 system

H8 Computer	$375
H8-1 4K Memory	140
H8-3 4K Chip Set	95
H8-5 Serial I/O and Cassette Interface	110
H9 Video Terminal	530
ECP-3801 Cassette Recorder/Player	55
If purchased separately,	$1305.00

Heath System price is **$1239.75***

Choose any of the Heath-recommended systems shown here, the specially-priced HS-11 system below, or "roll your own" with a selection of products you choose. Any way you do it, you'll get a top-value, high-performance system, and you'll SAVE 5%!

Here's how to qualify for the 5% computer systems discount:

1. Select either the H8 or H11 and one major peripheral (H9, H10 or LA36).
2. Choose the I/O interface, memory and software accessories you need.
3. Specify each in the spaces provided on the order blank.
4. Deduct 5% from the total price of the products (excluding shipping and handling charges).

*Systems illustrated already have discount prices calculated for you.

From time to time, Heath will offer specially priced total systems such as the HS-11 below. These systems will be discounted even deeper than 5% to provide you with even MORE value for your computer dollar!

SYSTEM TWO

H8 Computer	$375
Two H8-1 4K Memories	280
Two H8-3 4K Chip Sets	190
H8-5 Serial I/O and Cassette Interface	110
H8-13 Extended BASIC in Cassette Format	10
H9 Video Terminal	530
ECP-3801 Cassette Recorder/Player	55
If purchased separately,	$1550.00

Heath System price is **$1472.50***

SYSTEM THREE

The minimum recommended H11 system

H11 Computer	$1295
H11-1 4K Memory	275
H11-2 Parallel Interface	95
H11-5 Serial Interface	95
H9 Video Terminal	530
H10 Paper Tape Reader/Punch	350
If purchased separately,	$2640.00

Heath System price is **$2508.00***

SYSTEM FOUR

SAVE EVEN MORE on this specially-priced Heath HS-11 complete computer system!

H11 Computer	$1295
H11-1 4K Memory	275
H11-2 Parallel Interface	95
H11-5 Serial Interface	95
H10 Paper Tape Reader/Punch	350
H36 LA36 DEC Writer II	1495
If purchased separately,	$3605.00

$3350.00*

YOU SAVE $255!

HEATHKIT
CONTINUING EDUCATION
BASIC PROGRAMMING

NEW HEATHKIT SELF-INSTRUCTIONAL COMPUTER COURSES

These Heathkit self-instructional courses are designed to help you get the most from your computer investment, whether you buy your computer hardware from Heath or anywhere else. While many predeveloped software programs are available, the only way to realize the full value of your personal computer is to learn programming yourself. These courses use the PROVEN Heathkit individual learning techniques to give you a thorough understanding of programming, even if you have no prior knowledge or experience. They'll show you exactly how to make your personal computer system really personal!

BASIC PROGRAMMING SELF-INSTRUCTIONAL COURSE

This course teaches you how to program your computer using the popular BASIC language. BASIC (Beginner's All-Purpose Symbolic Instruction Code) is essential for hobby and personal computing; it is also widely used in education and business. The course covers all formats, commands, statements and procedures plus the creative aspects of computer programming, so you can make practical use of it in solving problems and creating your own unique programs. Like other Heathkit self-instructional courses, it uses programmed instructions backed by practical hands-on computer experiments and demonstrations to reinforce and personalize the text material. An optional final exam (passing grade 70%) brings you a Certificate of Achievement and 3.0 Continuing Education Units*. While the BASIC course is keyed to Heathkit computers, it is also equally applicable to any computer system using BASIC. Available after Oct. 20th, 1977.

EC-1100, Shpg. wt. 6 lbs. 29.95

*Continuing Education Units (CEU's) are nationally recognized means of acknowledging participation in non-credit adult education.

COMING SOON!

8080 Programming: Teaches you the machine and assembly language used with 8080-based computers. Shows you how to use the editor, assembler and debug software to create efficient programs. Ideal for the H8 and other 8080A based machines. Coming soon.

LSI-11 Programming: Shows you how to use editor, assembler, linker, debug and executive I/O software to create efficient programs. Applicable to H11 and most other Digital Equipment Corporation PDP-11 series computers. Coming soon.

COMING IN OCTOBER!
MICROPROCESSOR SELF-INSTRUCTIONAL COURSE

Learn how microprocessors operate and how to design with them. Covers applications, machine language programming, hardware I/O interfacing and much more. The course includes all IC's needed to perform exciting experiments. The microprocessor trainer used with the course features the popular 6800 microprocessor plus 256 bytes of RAM, a 1K ROM monitor, 6-digit hexadecimal display and hexadecimal keyboard. The Heathkit microprocessor course/trainer combo is the fast, easy low-cost way to learn about these important devices. Watch for it in our next catalog!

GENERAL COMPUTER BOOKS

Microcomputer Dictionary and Guide (Matrix). Comprehensive source of definitions and basic information on computers and related topics. A super reference source. A must for your library. **EDP-218** 17.95

Introduction to Microcomputers Vol. I (Osborne). Excellent introduction to microcomputers and fundamental computer concepts. **EDP-224** 7.50

Introduction to Microcomputers Vol. II (Osborne). Complete descriptions of all popular microprocessors, 8080, 6800, 6502, SC/MP, Z80, F8, 2650, etc. Good reference. **EDP-225** 12.50

How to Buy and Use Minicomputers and Microcomputers (Sams). A fundamental text on mini/micro operation and application. **EDP-227** 9.95

TV Typewriter Cookbook (Sams). Good text explaining I/O terminals, interfacing, etc. **EDP-226** 9.95

8080 BOOKS

Build a library to support your H8 computer or any 8080 based machine.

Bugbook III (E & L). Superior reference source on 8080 interfacing and programming. Includes experiments. **EDP-231** 15.00

Bugbook IIA (E & L). Serial I/O concepts and terminal interfacing. **EDP-232** 5.00

8080 Programming for Logic Design (Osborne). Programming and Using the 8080 microprocessor. **EDP-229** 7.50

8080 Software Gourmet Guide and Cookbook (Scelbi). Excellent source for 8080 programs and subroutines. **EDP-228** 9.95

Practical Microcomputer Programming: 8080 (Northern Technology). Machine/Assembly programming concepts for the 8080. **EDP-235** 21.95

6800 BOOKS

Great reference sources for your 6800 based computers.

6800 Programming for Logic Design (Osborne). Programming and using the 6800 microprocessor. **EDP-230** 7.50

6800 Software Gourmet Guide and Cookbook (Scelbi). Excellent source of commonly used 6800 programs. **EDP-233** 9.95

6800 Microprocessor Applications Manual (Motorola). Comprehensive review of typical 6800 applications, design solutions, etc. **EDP-244** 25.00

6800 Microprocessor Programming Manual (Motorola). Programming principles and examples for the 6800. **EDP-245** 10.00

H11/LSI-11/PDP-11 BOOKS

Here are several important reference sources to help you get the most value from your H11 Computer.

Minicomputer Systems: Organization and Programming (Prentice-Hall). Good basic text. Emphasis on the PDP-11. **EDP-238** 17.95

PDP-11 Programming (Algonquin). A programmed instruction text teaching the concepts of PDP-11 operation and programming. **EDP-239** 5.00

The Minicomputer in the Laboratory (Wiley). Operation, programming and applications of PDP-11 computers. **EDP-246** 19.50

GENERAL PROGRAMMING AND APPLICATIONS BOOKS

Assembly Level Programming (Lexington). Good basic book on assembly language programming of small computers. **EDP-236** 14.95

101 BASIC Computer Games (DEC). A classic. Have fun with your computer. **EDP-237** .. 7.50

BASIC Software Library, Vol. I. Complete lists of BASIC applications programs bookkeeping, games, pictures (graphics). **EDP-240** 24.95

BASIC Software Library, Vol. II. Math, engineering, plotting and statistical programs in BASIC. **EDP-241** 24.95

BASIC Software Library, Vol. III. Advanced business applications programs in BASIC. **EDP-242** 39.95

BASIC Software Library, Vol. IV. Games and business applications programs in BASIC. **EDP-243** 9.95

BASIC Software Library, Vol. V. Games, graphics, and useful math programs in BASIC. **EDP-251** 9.95

HEATH
Schlumberger

Heath Company, Dept. 334-330
Benton Harbor, Michigan 49022

ORDER FORM
Agreement

To remove order form cut out entire page along dotted line.

Gentlemen: Please send me the Heathkit Computer Products I have checked below. I understand that if I order products designated for future delivery Heath will do their best to ship within 30 days of those availability dates.

- ☐ H8 Computer at $375.00 each plus $5.40 shipping and handling.
- ☐ Qty. ________ H8-1 4K Memory(s) at $140.00 each plus $1.15 shipping and handling.
- ☐ Qty. ________ H8-3 4K Chip Set(s) at $95.00 each plus $1.15 shipping and handling.
- ☐ H8-2 Parallel Interface at $150.00 each plus $1.30 shipping and handling.
- ☐ H8-5 Serial I/O Cassette Interface at $110.00 plus $1.15 shipping and handling.
- ☐ H8-13 Extended BASIC Cassette at $10.00 each plus $1.15 shipping and handling.
- ☐ H8-14 Extended BASIC on paper tape at $10.00 each plus $1.15 shipping and handling.
- ☐ H8-15 Paper Tape Systems Software for H8 at $20.00 each plus $1.15 shipping and handling.
- ☐ HM-800 Manual Set at $25.00 each plus $2.37 shipping and handling.
- ☐ H11 Computer at $1295.00 each plus $5.52 shipping and handling.
- ☐ Qty. ________ H11-1 4K Memory(s) at $275.00 each plus $1.15 shipping and handling.
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- ☐ H11-5 Serial Interface at $95.00 each plus $1.15 shipping and handling.
- ☐ Please send the following Computer Books (order must total $10.00 minimum) postpaid (Print numbers plainly.)

____

____

- ☐ H11-6 Extended Arithmetic Chip at $159 each plus $1.15 shipping and handling.
- ☐ HM-1100 Manual Set at $25.00 each plus $2.50 shipping and handling.
- ☐ H9 Video Terminal at $530 each plus $7.64 shipping and handling.
- ☐ H10 Paper Tape Reader/Punch at $350 each plus $4.96 shipping and handling.
- ☐ H10-2 Three Rolls Paper Tape at $10.00 plus $1.15 shipping and handling.
- ☐ H10-3 Three boxes Fan-fold Paper Tape at $10.00 plus $1.15 shipping and handling.
- ☐ H36 DEC Writer II at $1495 (No COD's, see page 12 for shipping information.)
- ☐ H36-1 Fan-fold Paper at $30.00 plus $7.76 shipping and handling.
- ☐ H36-2 E1A Interface at $65.00 each plus $1.15 shipping and handling.
- ☐ ECP-3801 Cassette Recorder/Player at $55.00 each plus $1.69 shipping and handling.
- ☐ ECP-3802 Cassette Recording Tape. Pkg. of three at $5.00 plus $1.15 shipping and handling per pkg.
- ☐ EC-1100 BASIC Programming Course at $29.95 plus $1.69 shipping and handling. Available after October.
- ☐ HS-11 Special Priced Complete System at $3350 each plus $14.00 shipping and handling.

Note: The H11 and all its accessories will be available November 10th, 1977.

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You may purchase Heathkit products on our convenient Revolving Charge Plan. No money down and up to two years to pay. Up to $1500 maximum account balance.

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This form MUST accompany your H11 computer order.

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HEATH COMPANY

By William E. Johnson

CUSTOMER

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Customer's Signature

Heathkit is the name to look for in quality electronic kits

Heathkit Modulus—the total hi-fi system that changes to meet your changing needs

Heath Company, located on the shores of Lake Michigan near Benton Harbor, is the world's largest manufacturer of electronic kits. Heathkit products are marketed primarily through the Heathkit Mail Order Catalog, published 5 times a year, and a nationwide chain of Heathkit Electronic Centers (Units of Schlumberger Products Corporation).

In addition to this new line of personal computing products, Heath Company offers nearly 400 other electronic kits of virtually every description. Product categories include Amateur Radio, Automotive Accessories, Stereo Hi-fi Components, Test Instruments, Color TV, Boating and Marine Accessories, Leisure and Home Improvement Products, and our award-winning self-instruction programs. Every Heathkit product is supplied with a comprehensive step-by-step instruction manual that tells you all you need to know, from unpacking the kit to plugging it in. These manuals are world-famous for their clarity, accuracy and precision. Let Heath show you how easily you can put together superior quality electronic products. Send for your FREE copy of our latest catalog!

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Canadian Customers: Contact the Heathkit Electronic Center in most major cities or write for Canadian Prices to:

Heath Company, A Division of Schlumberger Canada, Ltd.
1480 Dundas Street E.
Mississauga, Ontario L4X 2R7

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Continued from page 128

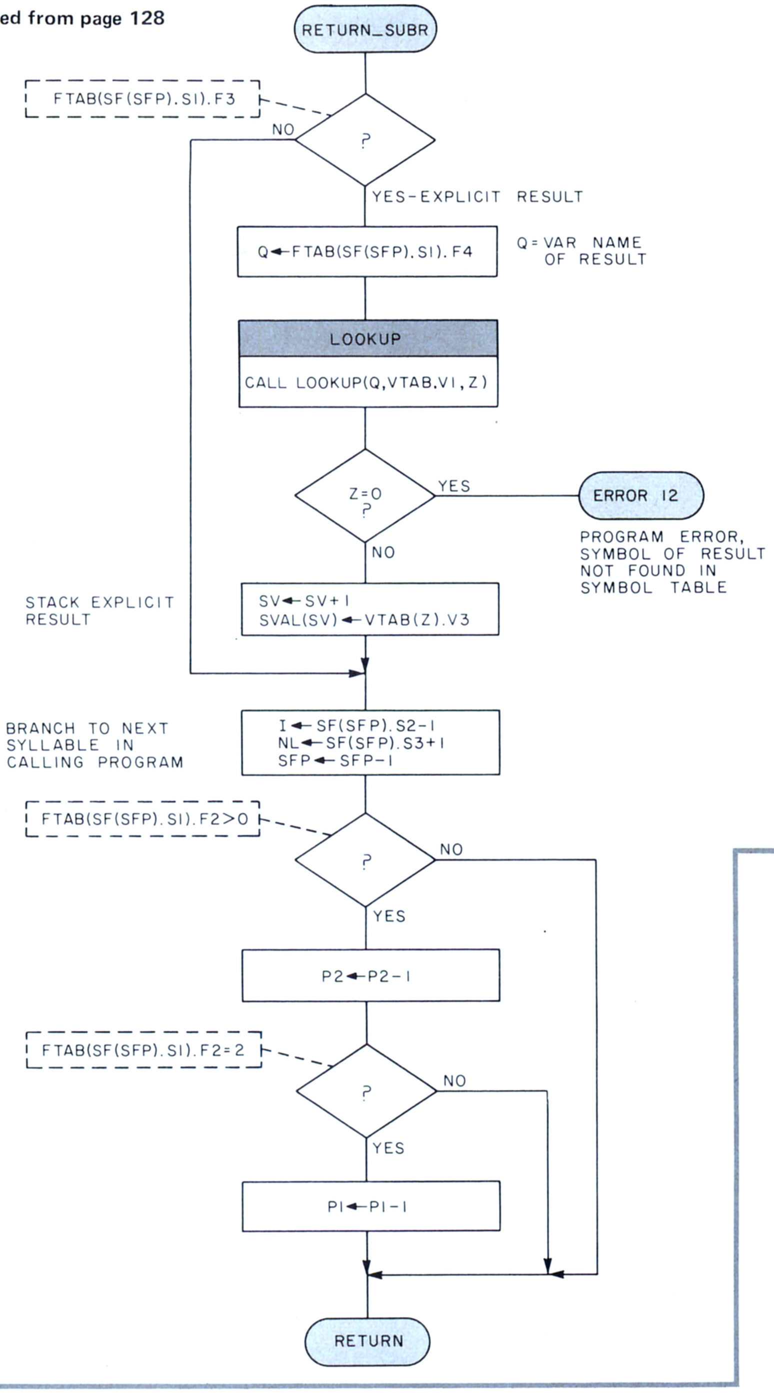
RETURN_SUBR
FTAB(SF(SFP).SI).F3
NO
?
YES-EXPLICIT RESULT
Q←FTAB(SF(SFP).SI).F4
Q = VAR NAME OF RESULT
LOOKUP
CALL LOOKUP(Q,VTAB.VI,Z)
Z=0 ?
YES
ERROR 12
PROGRAM ERROR, SYMBOL OF RESULT NOT FOUND IN SYMBOL TABLE
NO
STACK EXPLICIT RESULT
SV←SV+1
SVAL(SV)←VTAB(Z).V3
BRANCH TO NEXT SYLLABLE IN CALLING PROGRAM
I←SF(SFP).S2-1
NL←SF(SFP).S3+1
SFP←SFP-1
FTAB(SF(SFP).SI).F2>0
?
NO
YES
P2←P2-1
FTAB(SF(SFP).SI).F2=2
?
NO
YES
PI←PI-I
RETURN

Figure 14: The procedure used to return from a subroutine. If the subroutine had an explicit result, an indirect pointer to the result must be stacked in table SVAL. Information stacked in table SF by the call to the subroutine must be unstacked. Finally, before continuing the interpretation at the proper syllable, any actual parameter pointers stacked in tables SD1 and SD2 must be unstacked.

Statement branching and subroutine linkage is a relatively simple process compared with expression evaluation. The next few figures return us to our discussion of the interpreter itself by detailing the expression evaluation process.

THE PAIA 8700 COMPUTER/CONTROLLER

An exceptional price on an applications oriented 6503 based micro-processor system featuring:

- 1K bytes RAM locations (512 bytes supplied)
- 1K bytes ROM (256 byte monitor included)
- 2 - 8 bit input ports
- 2 - 8 bit output ports (1 latched, 1 buffered)
- 24 key touch operated keypad (used by monitor to allow entry & execution of user programs also user definable.)
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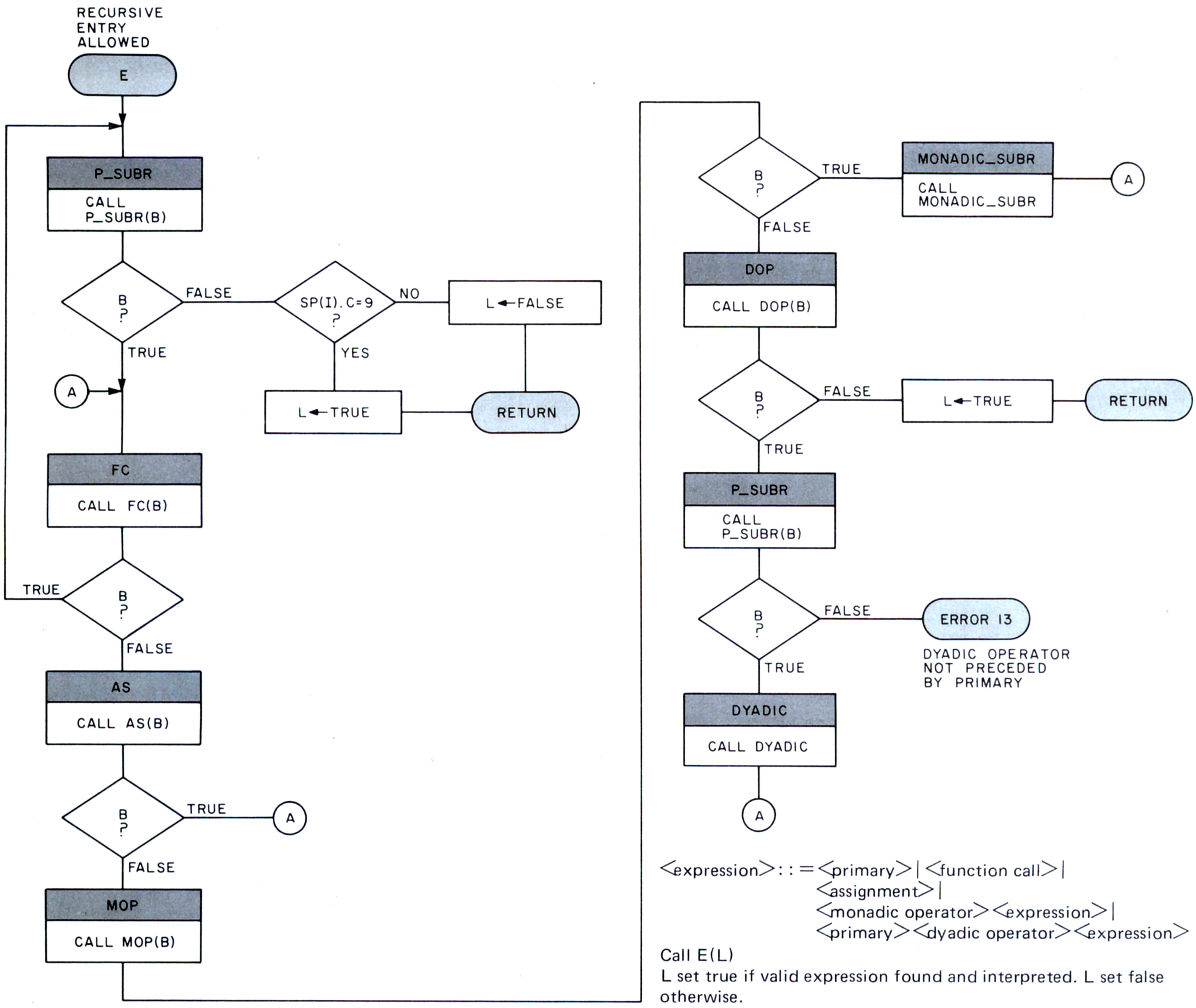
THE IDEAL, LOW COST SOLUTION TO IMPLEMENTING ALL THOSE WILD COMPUTER BASED CONTROL SYSTEMS YOU'VE BEEN DREAMING OF!

PAIA software currently available or under development includes: Music synthesizer interface: Home applications package including: multi-zone fire/burglar alarm, real time clock, energy saving heat/air conditioning control, computer generated "door-bell"; Model roalroad controller and more....................

8700 COMPUTER/CONTROLLER KIT $149.95
(requires 5v. @ 1.2A.; 12v. @ 150 ma.)
Shipped direct from PAIA (add $3.00 postage)

PAIA ELECTRONICS • DEPT. 7-B • 1020 W. Wilshire Blvd. • Oklahoma City, OK 73116
Also available at FULL-LINE Computer stores.

Circle 244 on inquiry card.


RECURSIVE ENTRY ALLOWED
E
P_SUBR
CALL P_SUBR(B)
B ?
FALSE
SP(I).C=9 ?
NO
L←FALSE
YES
L←TRUE
RETURN
TRUE
A
FC
CALL FC(B)
TRUE
B ?
FALSE
AS
CALL AS(B)
B ?
TRUE
A
FALSE
MOP
CALL MOP(B)
B ?
TRUE
MONADIC_SUBR
CALL MONADIC_SUBR
A
FALSE
DOP
CALL DOP(B)
B ?
FALSE
L←TRUE
RETURN
TRUE
P_SUBR
CALL P_SUBR(B)
B ?
FALSE
ERROR 13
DYADIC OPERATOR NOT PRECEDED BY PRIMARY
TRUE
DYADIC
CALL DYADIC
A

<expression>::=<primary>|<function call>|
<assignment>|
<monadic operator><expression>|
<primary><dyadic operator><expression>

Call E(L)
L set true if valid expression found and interpreted. L set false otherwise.

Figure 15: Subroutine E. This routine is called in figure 11 to recognize and interpret an expression. Five primary subroutines are invoked by E to interpret a valid expression. First P_SUBR is called to test for a valid primary which must be the rightmost token in any valid expression. After a primary is found, subroutine FC is called to test for and interpret a valid function call. If found, subroutine E starts again; otherwise, AS is called to look for a valid assignment. Subroutines MOP and DOP may also be called to look for monadic and dyadic operators, respectively (see figure 17). The total result is that a valid expression will be interpreted and argument L will be set true. In the case of an invalid or a nonexistent expression, argument L will be set false.

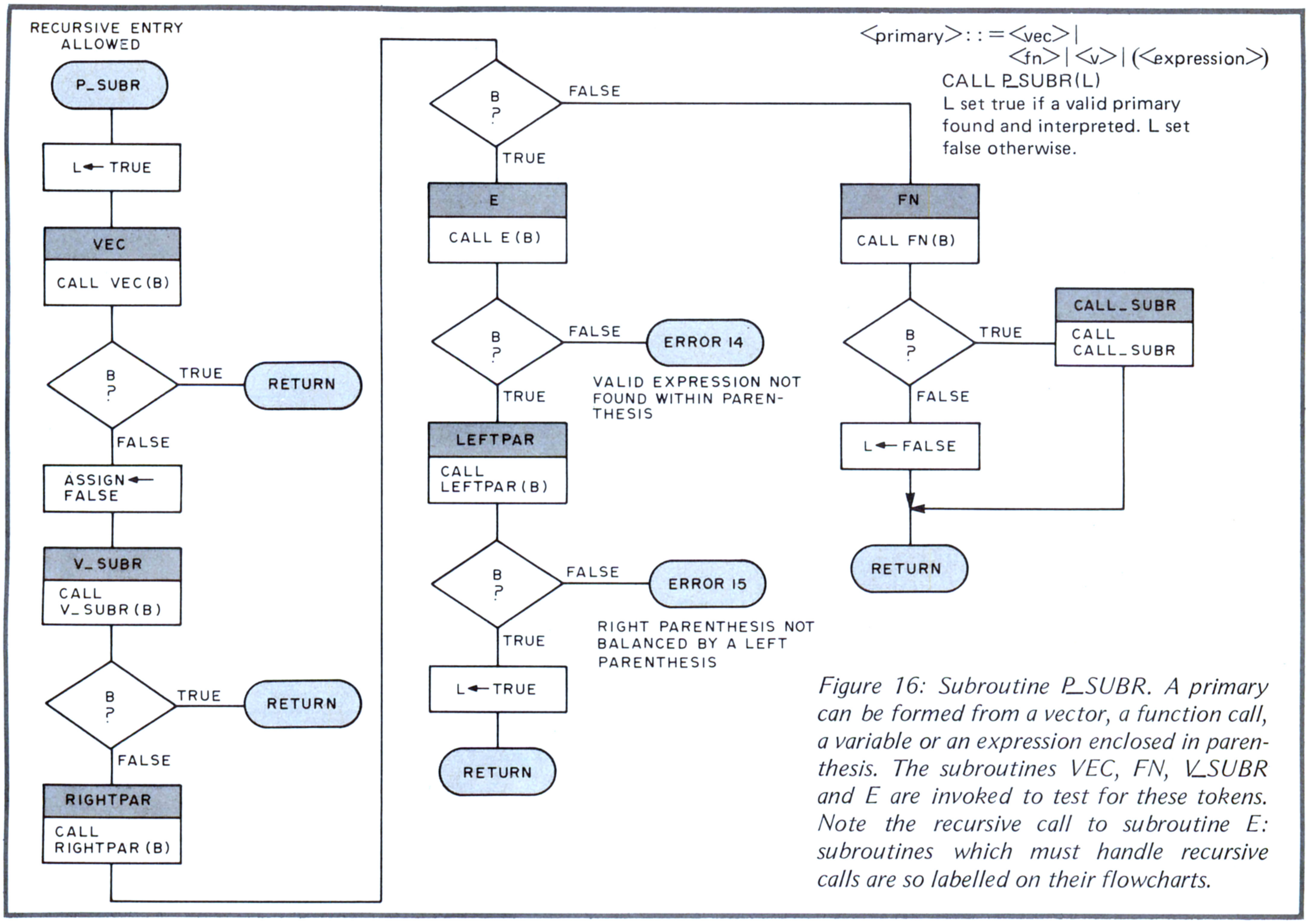

RECURSIVE ENTRY ALLOWED
P_SUBR
L ← TRUE
VEC
CALL VEC(B)
B ?
TRUE
RETURN
FALSE
ASSIGN ← FALSE
V_SUBR
CALL V_SUBR(B)
B ?
TRUE
RETURN
FALSE
RIGHTPAR
CALL RIGHTPAR(B)
B ?
FALSE
TRUE
E
CALL E(B)
B ?
FALSE
ERROR 14
VALID EXPRESSION NOT FOUND WITHIN PARENTHESIS
TRUE
LEFTPAR
CALL LEFTPAR(B)
B ?
FALSE
ERROR 15
RIGHT PARENTHESIS NOT BALANCED BY A LEFT PARENTHESIS
TRUE
L ← TRUE
RETURN
FN
CALL FN(B)
B ?
TRUE
CALL_SUBR
CALL CALL_SUBR
FALSE
L ← FALSE
RETURN
<primary>: : = <vec> | <fn> | <v> | (<expression>)
CALL P_SUBR(L)
L set true if a valid primary found and interpreted. L set false otherwise.

Figure 16: Subroutine P_SUBR. A primary can be formed from a vector, a function call, a variable or an expression enclosed in parenthesis. The subroutines VEC, FN, V_SUBR and E are invoked to test for these tokens. Note the recursive call to subroutine E: subroutines which must handle recursive calls are so labelled on their flowcharts.

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Circle 245 on inquiry card.

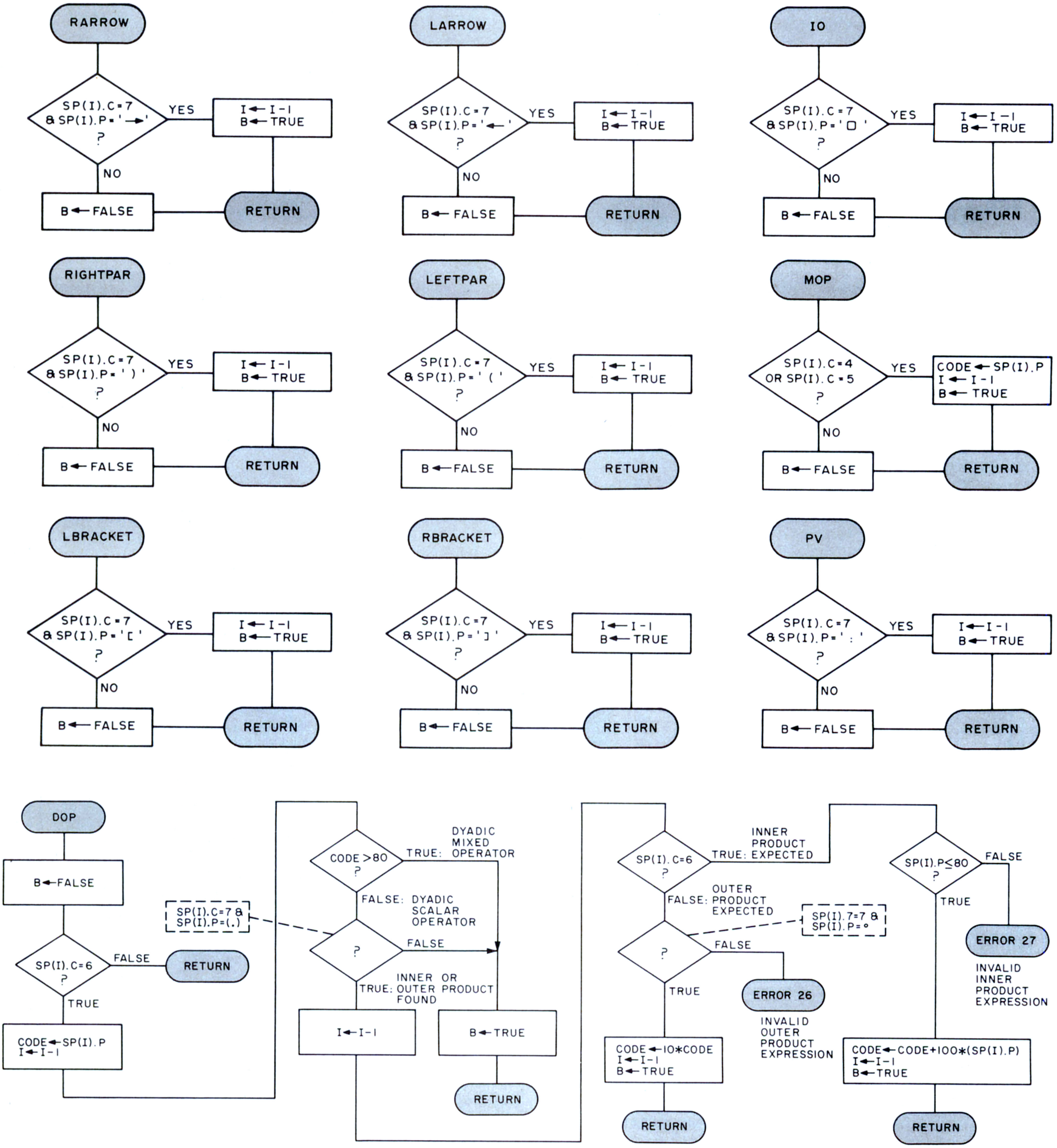
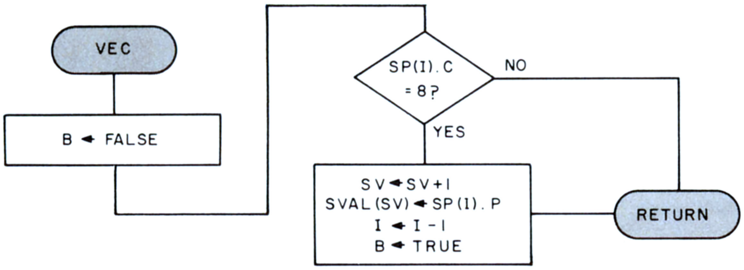
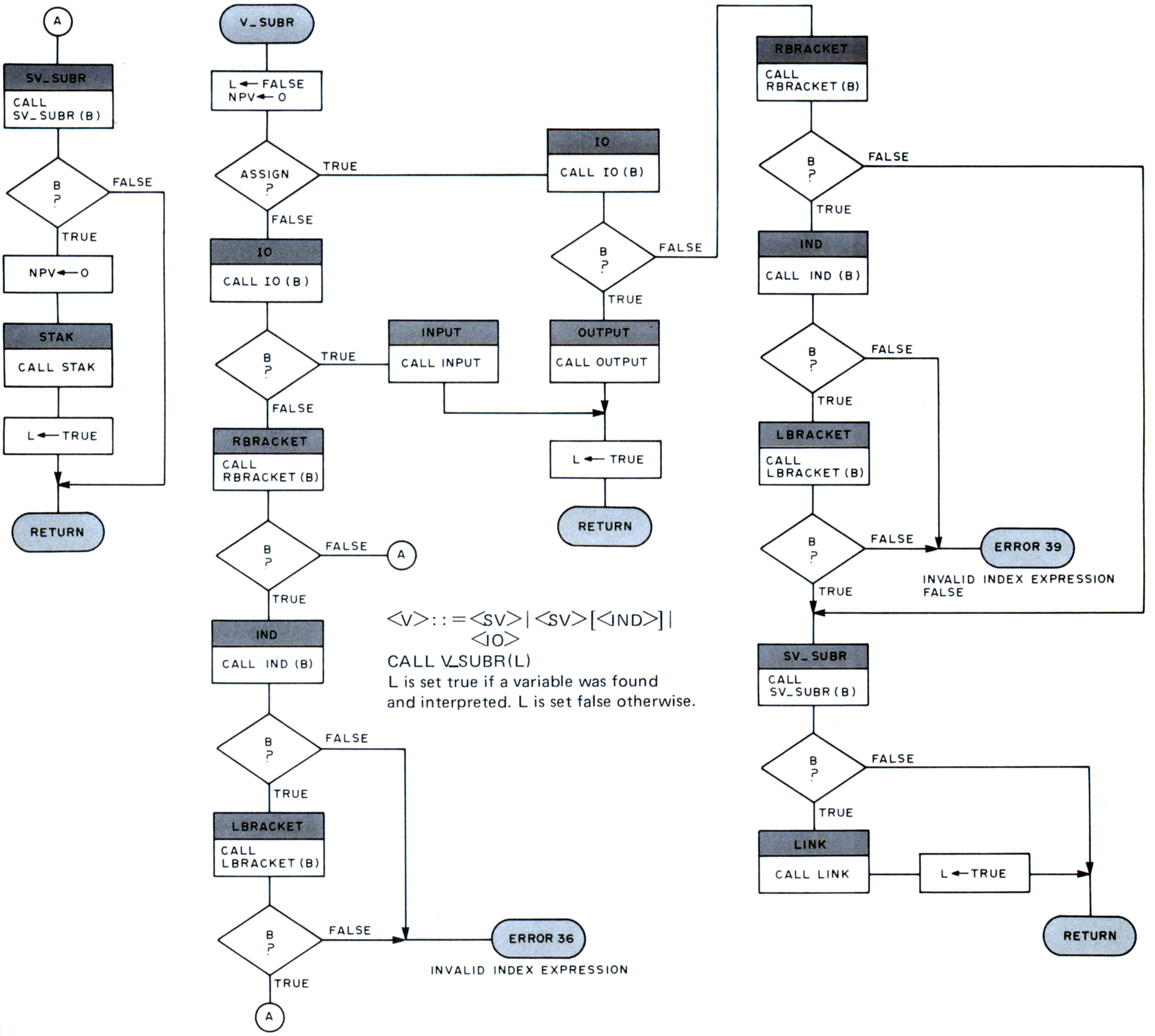

RARROW
SP(I).C=7 & SP(I).P='→' ?
YES
I←I-1
B←TRUE
NO
B←FALSE
RETURN
LARROW
SP(I).C=7 & SP(I).P='←' ?
YES
I←I-1
B←TRUE
NO
B←FALSE
RETURN
IO
SP(I).C=7 & SP(I).P='□' ?
YES
I←I-1
B←TRUE
NO
B←FALSE
RETURN
RIGHTPAR
SP(I).C=7 & SP(I).P=')' ?
YES
I←I-1
B←TRUE
NO
B←FALSE
RETURN
LEFTPAR
SP(I).C=7 & SP(I).P='(' ?
YES
I←I-1
B←TRUE
NO
B←FALSE
RETURN
MOP
SP(I).C=4 OR SP(I).C=5 ?
YES
CODE←SP(I).P
I←I-1
B←TRUE
NO
B←FALSE
RETURN
LBRACKET
SP(I).C=7 & SP(I).P='[' ?
YES
I←I-1
B←TRUE
NO
B←FALSE
RETURN
RBRACKET
SP(I).C=7 & SP(I).P=']' ?
YES
I←I-1
B←TRUE
NO
B←FALSE
RETURN
PV
SP(I).C=7 & SP(I).P=':' ?
YES
I←I-1
B←TRUE
NO
B←FALSE
RETURN
DOP
B←FALSE
SP(I).C=6 ?
FALSE
RETURN
TRUE
CODE←SP(I).P
I←I-1
CODE>80 ?
TRUE: DYADIC MIXED OPERATOR
FALSE: DYADIC SCALAR OPERATOR
SP(I).C=7 & SP(I).P=(.)
?
FALSE
TRUE: INNER OR OUTER PRODUCT FOUND
I←I-1
B←TRUE
RETURN
SP(I).C=6 ?
TRUE: INNER PRODUCT EXPECTED
FALSE: OUTER PRODUCT EXPECTED
SP(I).7=7 & SP(I).P=∘
?
FALSE
ERROR 26
INVALID OUTER PRODUCT EXPRESSION
TRUE
CODE←10*CODE
I←I-1
B←TRUE
RETURN
SP(I).P≤80 ?
FALSE
ERROR 27
INVALID INNER PRODUCT EXPRESSION
TRUE
CODE←CODE+100*(SP(I).P)
I←I-1
B←TRUE
RETURN

Figure 17: A collection of miscellaneous token recognition routines called by various routines in this APL interpreter. All subroutines in this figure have a single argument B which is set true if the particular token is found. B is set false otherwise.


VEC
B ← FALSE
SP(I).C = 8?
NO
YES
SV ← SV+1
SVAL(SV) ← SP(I).P
I ← I-1
B ← TRUE
RETURN

CALL VEC(B)
B is set true if a constant or vector is recognized; the recognized constant/vector being stacked. B is set false otherwise.

Figure 18: Interpretation of a vector or constant. If the current syllable indicates a constant or a vector, the pointer to the associated value is stored in table SVAL.


A
SV_SUBR
CALL SV_SUBR (B)
B ?
FALSE
TRUE
NPV ← 0
STAK
CALL STAK
L ← TRUE
RETURN
V_SUBR
L ← FALSE
NPV ← 0
ASSIGN ?
TRUE
FALSE
IO
CALL IO (B)
B ?
TRUE
FALSE
INPUT
CALL INPUT
RBRACKET
CALL RBRACKET (B)
B ?
FALSE
A
TRUE
IND
CALL IND (B)
B ?
FALSE
TRUE
LBRACKET
CALL LBRACKET (B)
B ?
FALSE
TRUE
A
ERROR 36
INVALID INDEX EXPRESSION
IO
CALL IO (B)
B ?
FALSE
TRUE
OUTPUT
CALL OUTPUT
L ← TRUE
RETURN
RBRACKET
CALL RBRACKET (B)
B ?
FALSE
TRUE
IND
CALL IND (B)
B ?
FALSE
TRUE
LBRACKET
CALL LBRACKET (B)
B ?
FALSE
TRUE
ERROR 39
INVALID INDEX EXPRESSION FALSE
SV_SUBR
CALL SV_SUBR (B)
B ?
FALSE
TRUE
LINK
CALL LINK
L ← TRUE
RETURN

<V>::=<SV>|<SV>[<IND>]|<IO>

CALL V_SUBR(L)
L is set true if a variable was found and interpreted. L is set false otherwise.

Figure 19: Interpretation of a variable. This process is more complicated than the interpretation of a constant. A variable can be formed from a variable, a simple variable followed by an index expression, or a quad operator. Further, variables occurring to the left of an assignment operator are handled differently from those on the right. Subroutines STAK and LINK (figures 25 and 26) handle the stacking of operand pointers and the linking of results to a symbol table entry.

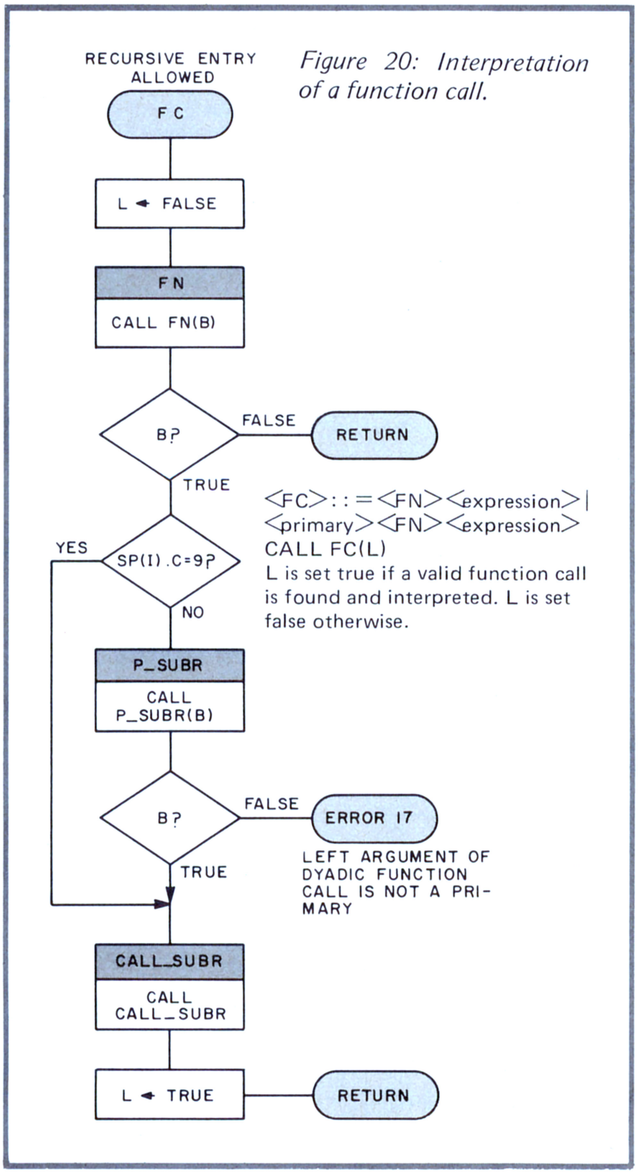
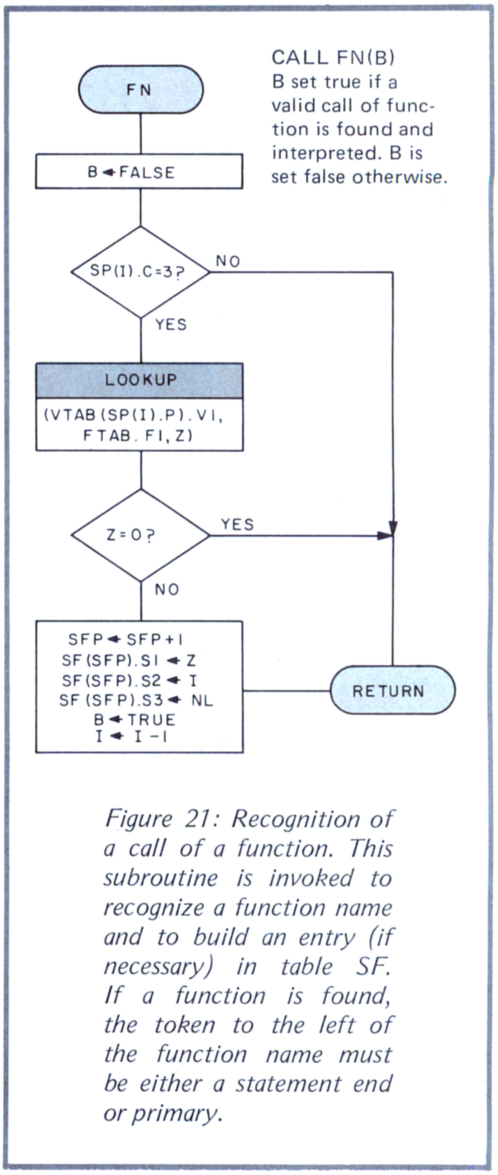

RECURSIVE ENTRY ALLOWED
FC
L ← FALSE
FN
CALL FN(B)
B?
FALSE
RETURN
TRUE
YES
SP(I).C=9?
NO
P_SUBR
CALL P_SUBR(B)
B?
FALSE
ERROR 17
TRUE
CALL_SUBR
CALL CALL_SUBR
L ← TRUE
RETURN

Figure 20: Interpretation of a function call.

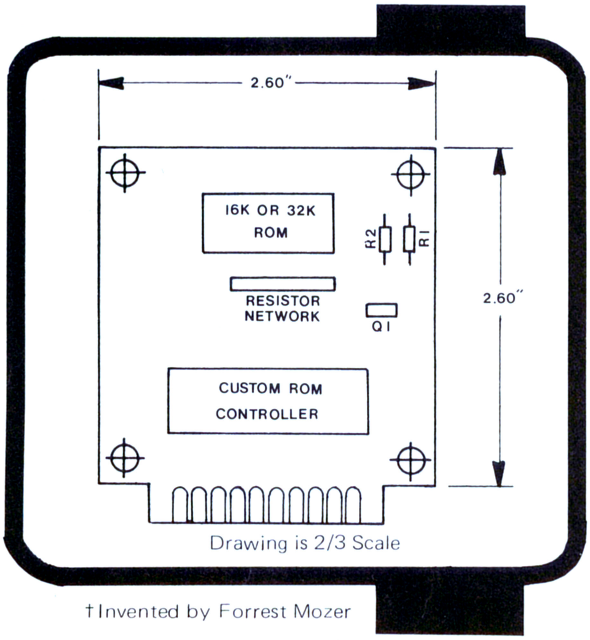
<FC>: : = <FN> <expression> |
<primary> <FN> <expression>
CALL FC(L)
L is set true if a valid function call is found and interpreted. L is set false otherwise.

LEFT ARGUMENT OF DYADIC FUNCTION CALL IS NOT A PRIMARY


FN
B ← FALSE
SP(I).C=3?
NO
YES
LOOKUP
(VTAB(SP(I).P).VI,
FTAB.FI,Z)
Z=0?
YES
NO
SFP ← SFP+1
SF(SFP).S1 ← Z
SF(SFP).S2 ← I
SF(SFP).S3 ← NL
B ← TRUE
I ← I-1
RETURN

CALL FN(B)
B set true if a valid call of function is found and interpreted. B is set false otherwise.

Figure 21: Recognition of a call of a function. This subroutine is invoked to recognize a function name and to build an entry (if necessary) in table SF. If a function is found, the token to the left of the function name must be either a statement end or primary.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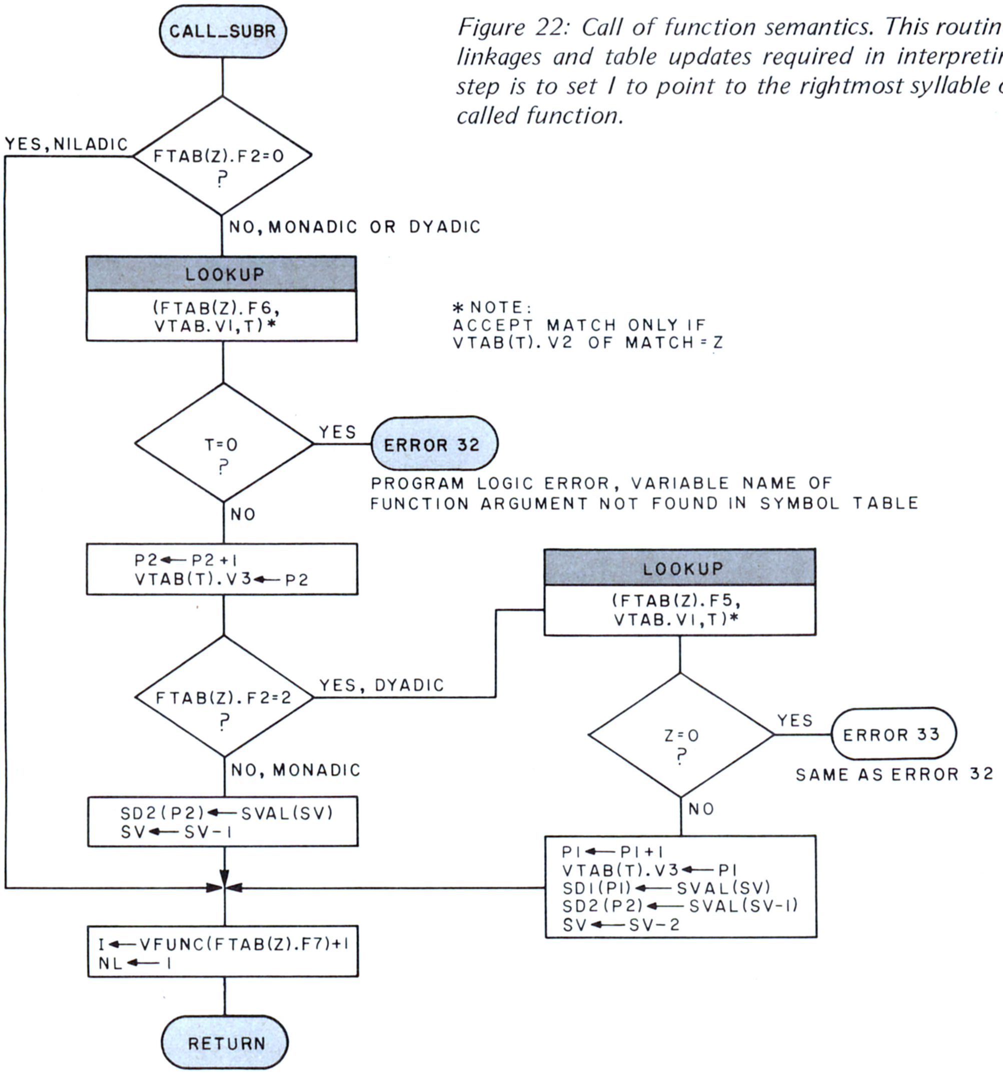
CALL_SUBR
FTAB(Z).F2=0 ?
YES, NILADIC
NO, MONADIC OR DYADIC
LOOKUP
(FTAB(Z).F6, VTAB.V1,T)*
*NOTE: ACCEPT MATCH ONLY IF VTAB(T).V2 OF MATCH=Z
T=0 ?
YES
ERROR 32
PROGRAM LOGIC ERROR, VARIABLE NAME OF FUNCTION ARGUMENT NOT FOUND IN SYMBOL TABLE
NO
P2←P2+1
VTAB(T).V3←P2
FTAB(Z).F2=2 ?
YES, DYADIC
NO, MONADIC
SD2(P2)←SVAL(SV)
SV←SV−1
LOOKUP
(FTAB(Z).F5, VTAB.V1,T)*
Z=0 ?
YES
ERROR 33
SAME AS ERROR 32
NO
P1←P1+1
VTAB(T).V3←P1
SD1(P1)←SVAL(SV)
SD2(P2)←SVAL(SV−1)
SV←SV−2
I←VFUNC(FTAB(Z).F7)+1
NL←1
RETURN

Figure 22: Call of function semantics. This routine is invoked to perform the linkages and table updates required in interpreting a function call. The last step is to set I to point to the rightmost syllable of the first statement in the called function.

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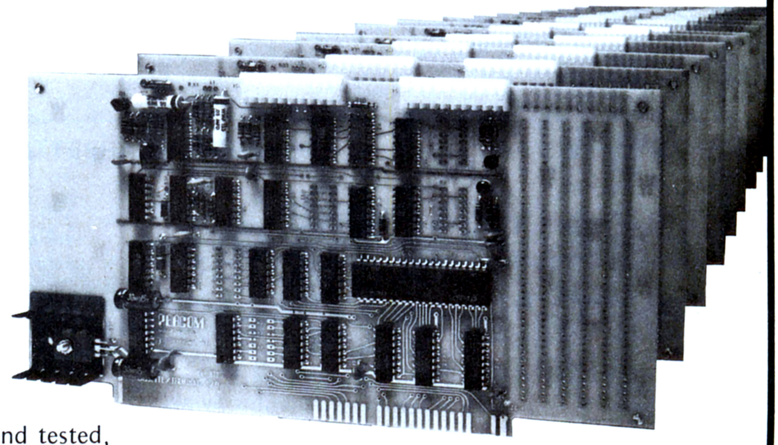

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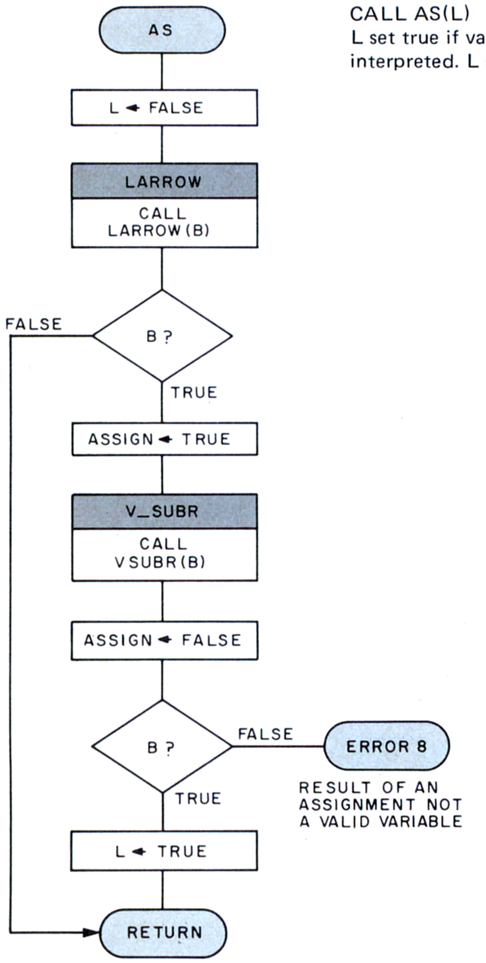
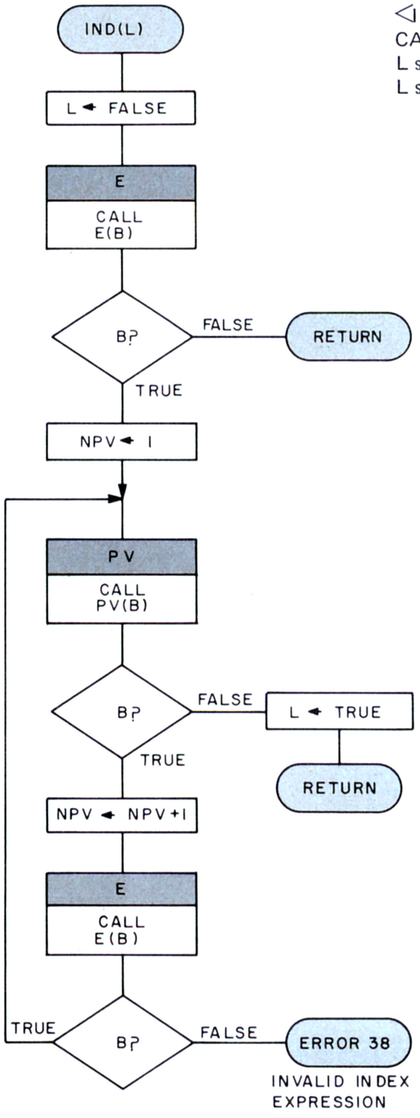

AS
L ← FALSE
LARROW
CALL LARROW(B)
FALSE
B ?
TRUE
ASSIGN ← TRUE
V_SUBR
CALL VSUBR(B)
ASSIGN ← FALSE
B ?
FALSE
ERROR 8
RESULT OF AN ASSIGNMENT NOT A VALID VARIABLE
TRUE
L ← TRUE
RETURN

CALL AS(L)
L set true if valid assignment found and interpreted. L set false otherwise.

Figure 23: Interpretation of an assignment. This routine searches for a valid assignment which must be of the form "variable ← expression." Again, subroutines LARROW and V_SUBR are called to interpret the appropriate tokens. V_SUBR is also called by P_SUBR (see figure 19), but it functions differently for the two calls, since one is looking for a variable to the right of an assignment symbol, and the other is looking for a variable to the left of an assignment symbol. Variable ASSIGN is used to signify which mode to use.


IND(L)
L ← FALSE
E
CALL E(B)
B?
FALSE
RETURN
TRUE
NPV ← I
PV
CALL PV(B)
B?
FALSE
L ← TRUE
RETURN
TRUE
NPV ← NPV+I
E
CALL E(B)
TRUE
B?
FALSE
ERROR 38
INVALID INDEX EXPRESSION

<IND>::=<E>|<IND>;<E>
CALL IND (L)
L set true if valid set of indices found.
L set false otherwise.

Figure 24: Recognition of a list of indices. This routine, which is called when an index expression (an expression enclosed within square brackets) is encountered, calls subroutine E recursively to evaluate the expression for each index and to stack a pointer to the result in stack SVAL. Upon completion, variable NPV indicates the number of index expressions encountered. Similarly, the top NPV entries in stack SVAL point to the values of these indices.

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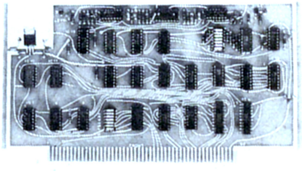

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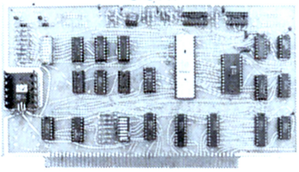

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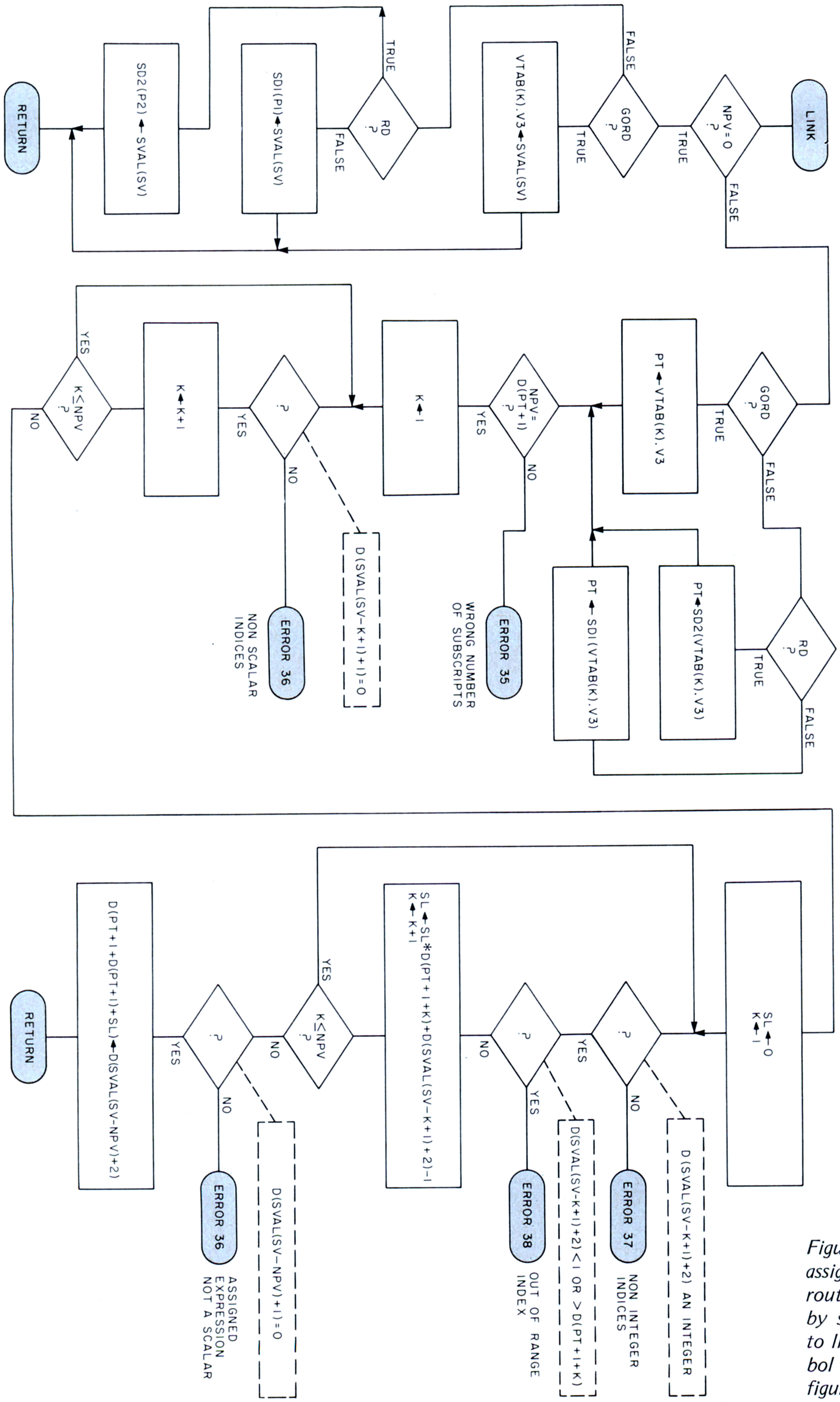
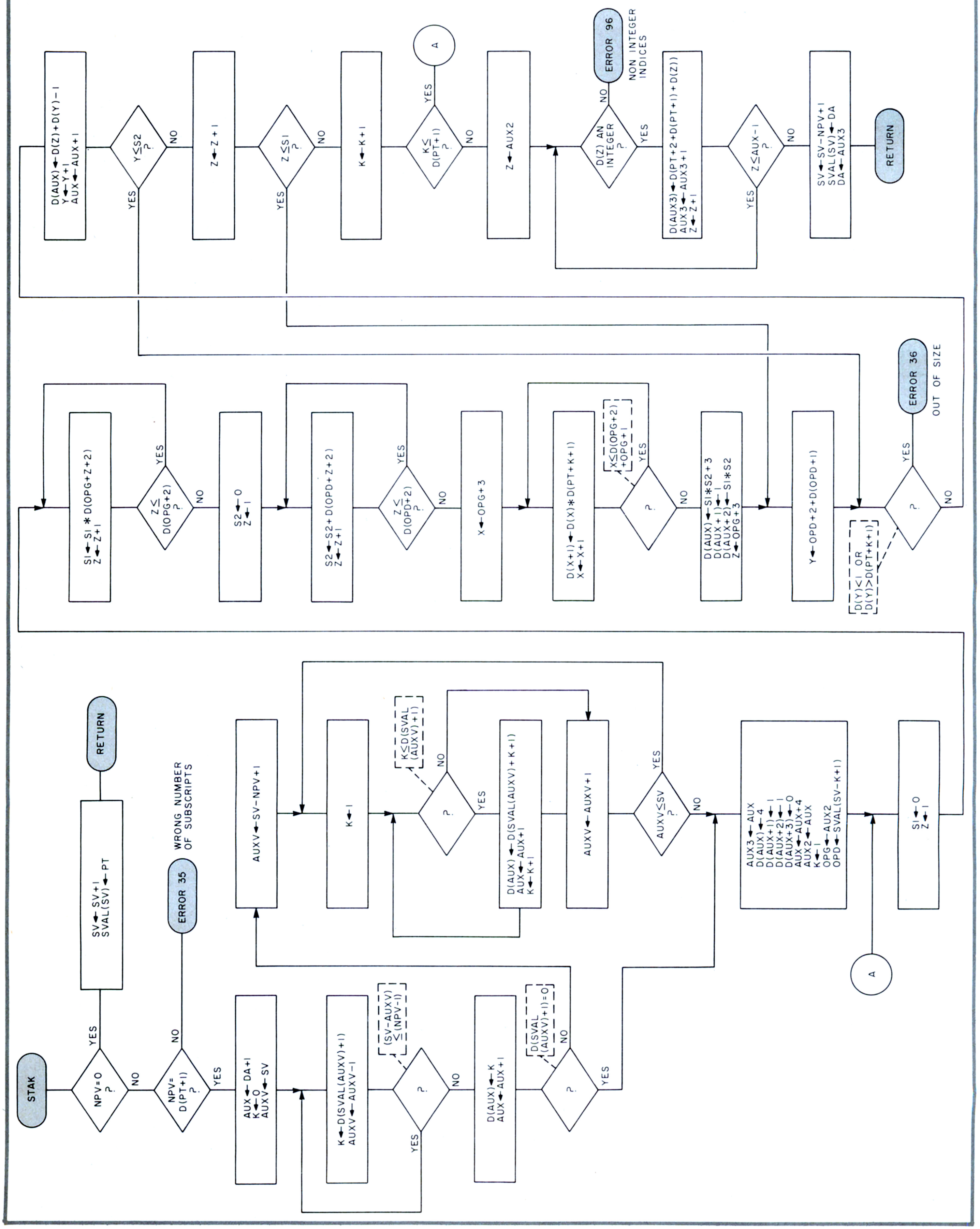
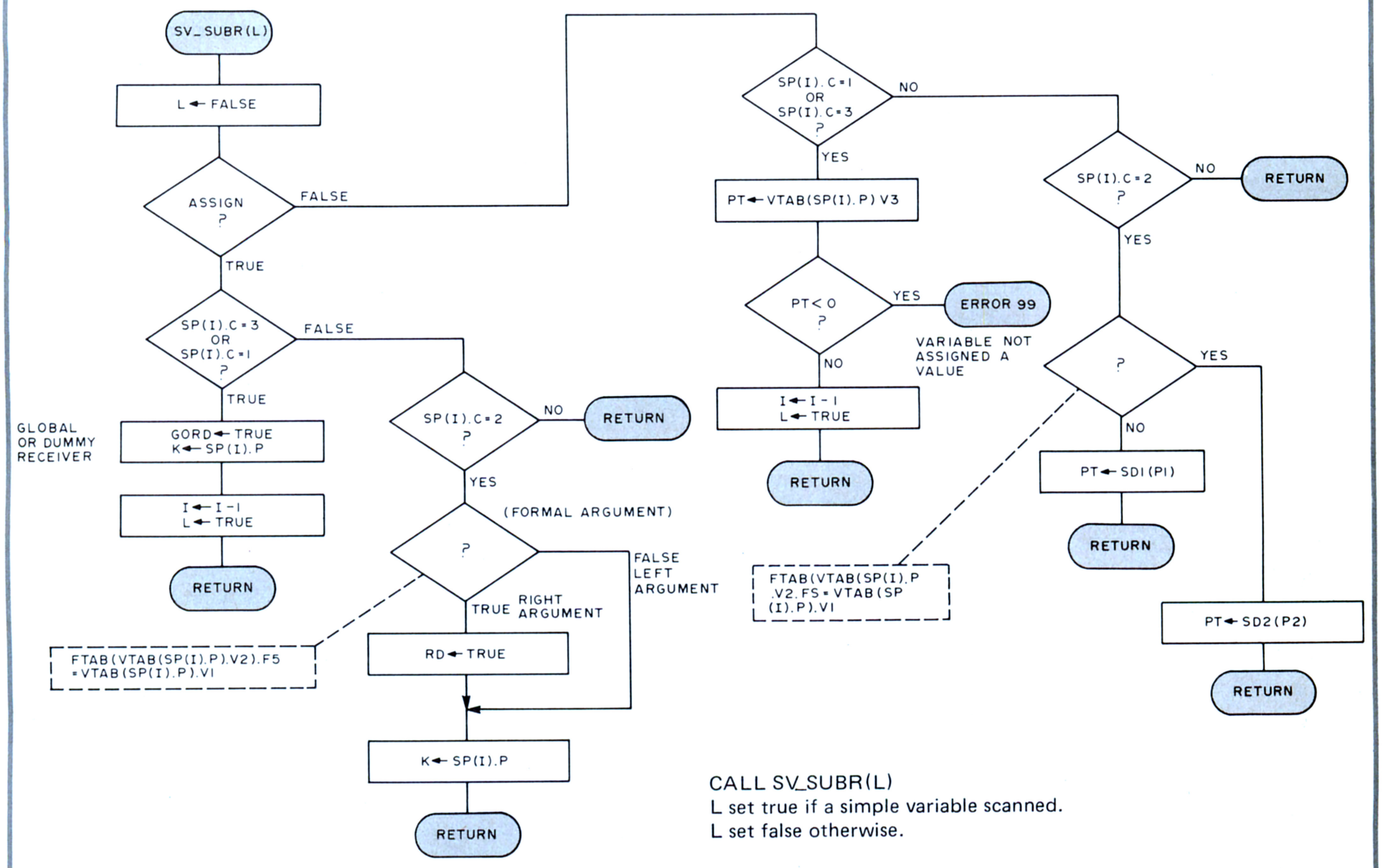

LINK
NPV=0 ?
TRUE
FALSE
GORD ?
TRUE
FALSE
VTAB(K).V3←SVAL(SV)
RD ?
FALSE
TRUE
SD1(P1)←SVAL(SV)
SD2(P2)←SVAL(SV)
RETURN
GORD ?
TRUE
FALSE
PT←VTAB(K).V3
RD ?
TRUE
FALSE
PT←SD2(VTAB(K).V3)
PT←SD1(VTAB(K).V3)
NPV= D(PT+1) ?
YES
NO
ERROR 35
WRONG NUMBER OF SUBSCRIPTS
K←1
?
YES
NO
D(SVAL(SV−K+1)+1)=0
ERROR 36
NON SCALAR INDICES
K←K+1
K≤NPV ?
YES
NO
SL←0
K←1
?
YES
NO
D(SVAL(SV−K+1)+2) AN INTEGER
ERROR 37
NON INTEGER INDICES
?
YES
NO
D(SVAL(SV−K+1)+2)<1 OR >D(PT+1+K)
ERROR 38
OUT OF RANGE INDEX
SL←SL*D(PT+1+K)+D(SVAL(SV−K+1)+2)−1
K←K+1
K≤NPV ?
YES
NO
?
YES
NO
D(SVAL(SV−NPV)+1)=0
ERROR 36
ASSIGNED EXPRESSION NOT A SCALAR
D(PT+1+D(PT+1)+SL)←D(SVAL(SV−NPV)+2)
RETURN

Figure 25: Linkage for assignment. This subroutine (LINK) is called by subroutine V SUBR to link results to a symbol table entry (see figure 19).

Figure 26: Subroutine STAK. This subroutine is called by subroutine V_SUBR to stack operand pointers (see figure 19).


STAK
NPV=0 ?
YES
NO
SV ← SV+1
SVAL(SV) ← PT
RETURN
NPV=D(PT+1) ?
NO
ERROR 35
WRONG NUMBER OF SUBSCRIPTS
YES
AUX ← DA+1
K ← 0
AUXV ← SV
K ← D(SVAL(AUXV)+1)
AUXV ← AUXV−1
?
(SV−AUXV) ≤ (NPV−1)
YES
NO
D(AUX) ← K
AUX ← AUX+1
?
D(SVAL(AUXV)+1)=0
NO
YES
AUXV ← SV−NPV+1
K ← 1
?
K≤D(SVAL(AUXV)+1)
NO
YES
D(AUX) ← D(SVAL(AUXV)+K+1)
AUX ← AUX+1
K ← K+1
AUXV ← AUXV+1
AUXV≤SV ?
YES
NO
AUX3 ← AUX
D(AUX) ← 4
D(AUX+1) ← 1
D(AUX+2) ← 1
D(AUX+3) ← 0
AUX ← AUX+4
AUX2 ← AUX
K ← 1
OPG ← AUX2
OPD ← SVAL(SV−K+1)
A
S1 ← 0
Z ← 1
S1 ← S1 * D(OPG+Z+2)
Z ← Z+1
Z ≤ D(OPG+2) ?
YES
NO
S2 ← 0
Z ← 1
S2 ← S2+D(OPD+Z+2)
Z ← Z+1
Z ≤ D(OPD+2) ?
YES
NO
X ← OPG+3
D(X+1) ← D(X)*D(PT+K+1)
X ← X+1
?
X≤D(OPG+2)+OPG+1
YES
NO
D(AUX) ← S1*S2+3
D(AUX+1) ← 1
D(AUX+2) ← S1*S2
Z ← OPG+3
Y ← OPD+2+D(OPD+1)
?
D(Y)<1 OR D(Y)>D(PT+K+1)
YES
NO
ERROR 36
OUT OF SIZE
D(AUX) ← D(Z)+D(Y)−1
Y ← Y+1
AUX ← AUX+1
Y≤S2 ?
YES
NO
Z ← Z+1
Z≤S1 ?
YES
NO
K ← K+1
K≤D(PT+1) ?
YES
A
NO
Z ← AUX2
D(Z) AN INTEGER ?
NO
ERROR 96
NON INTEGER INDICES
YES
D(AUX3) ← D(PT+2+D(PT+1)+D(Z))
AUX3 ← AUX3+1
Z ← Z+1
Z≤AUX−1 ?
YES
NO
SV ← SV−NPV+1
SVAL(SV) ← DA
DA ← AUX3
RETURN


SV_SUBR(L)
L ← FALSE
ASSIGN ?
FALSE
TRUE
SP(I).C=3 OR SP(I).C=1 ?
FALSE
TRUE
GLOBAL OR DUMMY RECEIVER
GORD ← TRUE K ← SP(I).P
I ← I-1 L ← TRUE
RETURN
SP(I).C=2 ?
NO
RETURN
YES
(FORMAL ARGUMENT)
?
FALSE LEFT ARGUMENT
TRUE RIGHT ARGUMENT
FTAB(VTAB(SP(I).P).V2).F5 = VTAB(SP(I).P).V1
RD ← TRUE
K ← SP(I).P
RETURN
SP(I).C=1 OR SP(I).C=3 ?
NO
YES
PT ← VTAB(SP(I).P) V3
PT<0 ?
YES
ERROR 99
VARIABLE NOT ASSIGNED A VALUE
NO
I ← I-1 L ← TRUE
RETURN
SP(I).C=2 ?
NO
RETURN
YES
?
YES
NO
PT ← SD1(P1)
RETURN
FTAB(VTAB(SP(I).P .V2.FS = VTAB(SP (I).P).V1
PT ← SD2(P2)
RETURN

CALL SV_SUBR(L)
L set true if a simple variable scanned.
L set false otherwise.

Figure 27: Linkage for a variable. This routine is called to recognize a simple variable. After it has been executed, variable GORD is set true if either a global or a dummy receiver is found. If the receiver is a formal argument, then RD is set true if the variable is the right argument of the function call, and set false if the variable is the left argument. For a simple variable to the left of an assignment, K is set to point to the associated VTAB entry; and for variables to the right of an assignment, PT is set to point to the D entry or value of the variable.

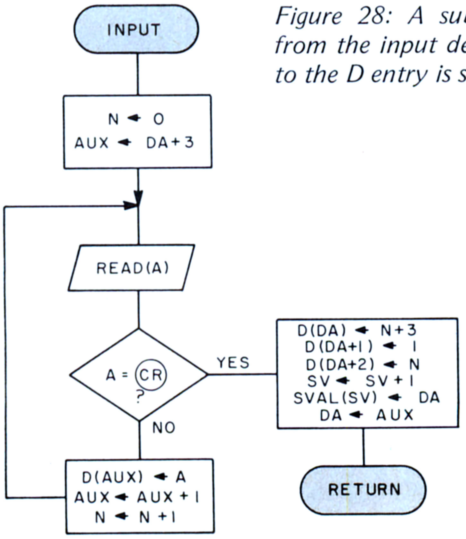

INPUT
N ← 0 AUX ← DA+3
READ(A)
A = (CR) ?
YES
NO
D(AUX) ← A AUX ← AUX+1 N ← N+1
D(DA) ← N+3 D(DA+1) ← 1 D(DA+2) ← N SV ← SV+1 SVAL(SV) ← DA DA ← AUX
RETURN

Figure 28: A subroutine used to input a constant vector. A value is read from the input device, an appropriate entry is made in table D, and a pointer to the D entry is stacked in table SVAL.

Note: *No flowchart is shown for a quad denoting output, since the process is more or less implementation dependent (although simple). The element in the top of stack SVAL points to the table D entry to be listed.*

That concludes part 2 of this 3 part series of articles describing an APL interpreter. Although the flowcharts may look awesome, the actual amount of code to be written is not overly great. My PL/I version of this interpreter is less than 1600 statements long.

Next month's concluding article describes the mathematical processing section of the statement interpreter, and describes the four arithmetic processing subroutines MOP, MONADIC, DOP and DYADIC. Since they define the number and use of the primitive operators, most of the tailoring of the interpreter will be done in these subroutines.■

Continued from page 43

through a resistor that sets the current flowing into pin 14 to approximately 2 mA.

An additional resistor, R_1 (also in this current leg), allows the current to be varied by a small percentage and provides the ability to adjust the full scale range of the digital to analog converter. The output of the converter is a current which is equivalent to the product of this reference current and the binary data on the control lines. The current is converted to a voltage through IC9 and can be zero offset through the use of the offset adjustment pot, R2.

The digital code stored in the scratch pad and presented to the digital to analog converter is in offset binary. A binary value of 00 000 000 produces an output of −5 V from the converter while 11 111 111 is equivalent to +5 V. In offset binary, if the most significant bit is a zero, the output is negative and if the most significant bit is a one, the output is positive. Since the converter has a range of 10 V, and is an 8 bit device, the resolution of the converter is 1/256 of 10 V, or approximately 40 mV. This means that the smallest output increments will be in 40 mV steps. To change this to finer increments requires that the range be shorter, such as +2.56 V to −2.56 V. By adjusting the span and zero pots, any reasonable range may be chosen, but the resolution will always be equal to the least significant bit or 1/256 of the range, and accuracy is estimated to be ±1/2 least significant bit.

INTERFACE ASSEMBLY AND CALIBRATION

1. Be sure to build the circuit with good quality sockets for all integrated circuits. With all components except integrated circuits wired in place, and presuming that there are no shorts, apply power to the interface. It should be noted that while the interface is shown with Altair (S-100) bus notation, there is no requirement that it be an S-100 configuration. The digital to analog conversion will work with any computer capable of providing an 8 bit data bus, 8 bit IO address bus, and an output enable strobe. Computer cycle time and architecture are irrelevant. For use with a Digital Group 8080 system, the address and data buses are connected to the equivalent DGS pin numbers, S-100 pin 77 on the interface board is grounded, and the DGS pin 17 IO write signal is used on pin 45 of the interface board in place of Sout.

2. Using a meter, check to see that the right supply voltages are on the appropriate integrated circuit pins and that V_{ref} on the digital to analog converter is approximately 6.2 V. If substituting parts, take care not to exceed 15 V between Vcc and Vee on the CMOS 4051.

3. Disconnect the power and attach the port decoding jumpers for the desired port addresses. Each of the six address lines, A7 thru A2, can be, by the appropriate placement of the jumpers, decoded as an inverted or noninverted signal. In building the circuit from scratch, an appropriate technique is to use a DIP socket with each pin, used as a jumper terminal. Selective wiring between the pins can then be done with wire wrap or Vector Slit-N-Wrap. The inverted choice is designated as a zero code, and the noninverted as a one. If all jumpers were set to the one position, channel 1's port address would be decoded as binary $11\ 111\ 100_2$, or octal 374. Channel 4 would be 377 octal. If all jumpers were set to zeros, channel 1 would start at port address 0 and channel 4 would be port address 3 octal. Pick the binary code for whatever port assignment desired and wire the jumpers.

4. Insert integrated circuits IC1, 2, 3, 4, 5, 7 and 9. Apply the power, and with a short program which just outputs a value from the accumulator to an output port, output a binary 10 000 000 to the port address corresponding to channel 4 on the interface board. Using a meter to monitor the output of the LM301A, adjust the zero pot R2 until the output is 0 V. With the same programming technique, load a binary 11 111 111 (octal 377) to channel 4 port address and adjust the span pot R1 for a meter reading of +5.12 V. A binary setting of 00 000 000 should output −5.12 V. If you are unsuccessful at this point, with power off, remove the MC1408L-8 and the LM301A, and verify that the binary output of the scratch pad is correct. With the integrated circuits presently installed, the scratch pad is latched at an address of channel 4. Nine times of of ten, problems like this can be attributed to choosing an incorrect port code. Turn off the power.

5. Insert the clock generator IC6, reapply power, and using a scope or frequency counter, verify an approximate 200 kHz clock rate. Turn off the power.

6. Next, insert IC8, the CMOS multiplexer IC10, and the sample and hold op amps IC11 and 12. Be very careful in handling the CMOS integrated circuit. It is very easily damaged by static charges. Turn on the power and then using the same simple program, output a binary value to one of the channel addresses and note with a meter that it is in fact the correct voltage. Using the program, vary the output of each channel separately across the range and note that no other channel outputs should change. Sympathetic tracking usually indicates a bad multiplexer integrated circuit.

A few cautions: Don't use op amps with a frequency response less than the LM301A and use only the L8 version of the MC1408-L8 (not MC1408-L7 or MC1408-L6) if you want a guaranteed eight bits of precision.

```
80 REM THIS PROGRAM CALCULATES THE VALUES FOR A SINE WAVE AND
82 REM PUTS THEM IN PAGE 100 (OCTAL) OF MEMORY
90 PRINT “SINE WAVE POINT CALCULATOR”
100 LET A=3.14/180*360/256
110 FOR B=0 TO 255
120 LET W=INT(127.5+(127.5*SIN(A*B))
130 FILL 16384+B,W
160 NEXT B
```

Listing 1: An extended BASIC program to compute and load a table in memory with 256 sample points of a sinusoidal waveform. Digital Group MaxiBASIC interpreter.

Now How Do I Use It?

Once you have conquered the hardware and constructed an interface (see notes in the box) you should be ready to exercise it under program control. There are some interesting applications using the digital to analog interface alone, none the least of which is Ned's problem.

You will remember that my solution to the impulse response problem in Ned's test setup was to vary the pressure sinusoidally using a computer generated voltage to control a pressure regulator. Adding a computer sounds a bit unnecessary, but remember that an analog to digital interface will be attached for data acquisition.

With this particular digital to analog interface, programming an analog control voltage utilizing an extended BASIC such as the Digital Group's MaxiBASIC, is quite easy. To operate a real time sine wave that varies the pressure between 0 and 10,000 PSIG requires a control regulator with a control voltage range of –5 V to +5 V and the following very simple BASIC program:

```
 90 REM THIS PROGRAM CALCULATES
    AND OUTPUTS A SINE WAVE.
100 LET A = 3.14/180*360/256
110 FOR B = 0 to 255
120 LET W = INT(127.5+127.5*SIN(A*B))
130 OUT 252,W
140 NEXT B
150 END
```

This program calculates 256 values of a sine wave with an amplitude of –5 to +5 V. When run in real time, the period of the waveform is about two seconds. The period is basically set by the time it takes to compute the expression on line 120 some 256 times. An alternative method is to calculate the points once, load the values in memory and call a subroutine which scans the table when directed to do so by the program.

The first time that the points are computed, it will take two seconds as before. Then they are available in a look up table. A program which constructs such a memory resident table is illustrated in listing 1. Photo 2 shows an oscilloscope trace of the synthesized sine wave created by the digital to analog converter in figure 9 using the table created by listing 1.

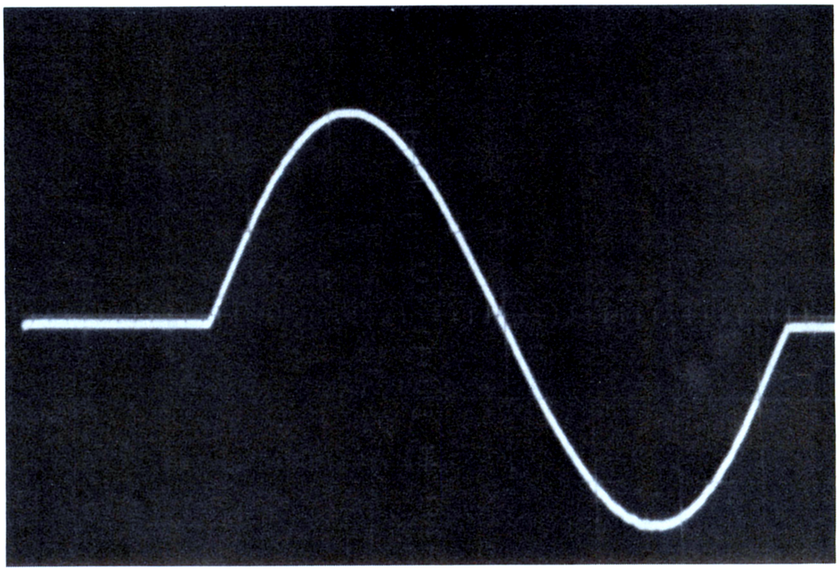


Photo 2: An oscilloscope display of a sinusoidal waveform synthesized by using the BASIC program in listing 1 in conjunction with the digital to analog converter shown in figure 9.

Split Octal Address	Octal Code	Operation	Commentary
012/000	041 000 100	LXI H&L	Set the program counter to page 100;
012/003	176	MOV A	Move addressed memory to accumulator;
012/004	323 375	OUT	Output accumulator to port 375;
012/006	054	INR L	Increment L register;
012/007	302 003 012	JMP COND.	Jump to 012/003 if L ≠ 0;
012/012	311	RET	Return to BASIC program;

Listing 2: A machine language program which is used to drive the digital to analog converter in figure 9. This program is called by the extended BASIC program in listing 3.

```
300  PRINT “THIS PROGRAM WHICH DRIVES AN 8 BIT D/A PRODUCES  ”
310  PRINT “ANY WAVEFORM FROM A BINARY TABLE”
400  REM THIS PROGRAM CALLS A SUBROUTINE AT 012/000 (OCTAL)
410  REM WHICH OUTPUTS THE 256        WAVEFORM VALUES TO
420  REM D/A ON OUTPUT PORT 375(OCTAL)
430  REM OCTAL AT 012/000
440  REM 041 000 100 176 323 375 054 302 003 012 311
450  REM MAX SPEED FOR ADSR IS 4 MSEC.
470  REM BINARY TABLE IS ON PAGE 100 (OCTAL)
502  PRINT “GENERATE THE WAVEFORM HOW MANY TIMES ?”:INPUT E
505  FOR X=1 TO E
510  LET A=CALL(2560,0)
515  NEXT X
1000  END
```

Listing 3: An extended BASIC program which calculates 256 points of a given waveform which is to be synthesized and then calls the machine language routine in listing 2 to actually drive the digital to analog converter in figure 9. The call to the subroutine in listing 2 occurs at line 510 of this program. Digital Group MaxiBASIC interpreter.

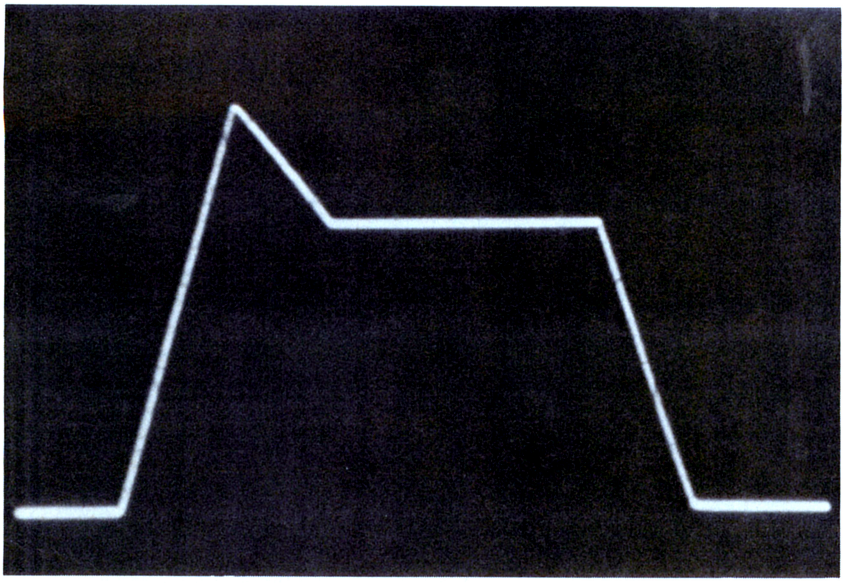


Photo 3: An oscilloscope display of a musical envelope waveform called an ADSR waveform. "ADSR" stands for Attack, Decay, Sustain and Release, a popular way of characterizing an amplitude envelope which is typical for many musical instrument waveforms. This waveform was synthesized by means of the program in listing 4 which was used to drive the digital to analog converter in figure 9. Also see figure 10.

```
80 PRINT "ADSR MEMORY LOADER"
90 REM THIS PROGRAM COMPUTES DECIMAL VALUES FOR A PIECE-WISE
91 REM LINEAR ADSR WAVEFORM AND ILLUSTRATES THE METHOD
92 REM THE VALUES ARE THEN LOADED INTO PAGE 100(OCTAL) OF MEMORY
93 REM THEY ARE THEN AVAILABLE FOR MACHINE SUBROUTINES
100 FOR X=0 TO 60
105 REM THIS IS THE "A" SECTION
110 LET Y=INT((255/60)*X)
120 FILL 16384+X,Y
125 NEXT X
130 LET W=61
135 FOR Z=0 TO 39
137 REM THIS IS THE "D" SECTION
140 LET Y=INT((-75/40)*Z+255)
150 FILL 16384+W,Y
152 LET W=W+1
155 NEXT Z
160 FOR X=101 TO 220
170 LET Y=180
172 REM THIS IS THE "S" SECTION
175 FILL 16384+X,Y
180 NEXT X
185 LET N=221
190 FOR X=0 TO 34
192 REM THIS IS THE "R" SECTION
200 LET Y=INT((-180/35)*X+180)
210 FILL 16384+N,Y
212 LET N=N+1
220 NEXT X
1000 END
```

Listing 4: An extended BASIC program which generates a table of sample points of the ADSR waveform whose graph appears in figure 10. Digital Group MaxiBASIC interpreter.

A simple program which scans the table and drives the digital to analog converter is assembled into the memory of my particular system at split octal address 012/000 (hexadecimal 0A00) as shown in listing 2. This program can be called at any time with the BASIC command CALL (2560,0), and when driven at faster than 100 ms periods can be easily displayed on an oscilloscope. *[Note that 2560 is decimal for split octal address value 012/000 or hexadecimal 0A00.]* The program in listing 3 incorporates the routine in listing 2 as a called subroutine and can be used to display any waveform defined by the table located at address 100/000 in split octal notation (hexadecimal 4000).

On to Bigger and Better Applications

An obvious application of this programming technique is to mathematically compute and generate complex waveforms which would otherwise require extensive dedicated hardware to duplicate. Music application is an area which is being heavily infiltrated with computer technology. A composer interested in electronic music effects can design discrete waveforms, display and review them before committing them to a performance design.

An alternative approach is to use BASIC to generate all the tables defining envelope or waveform aspects of desired instruments and then let BASIC sit idle while a machine language program selects and calls the tables to produce a musical score.

It's often easier to illustrate one example rather than discuss volumes of theory. One of the least complicated musical envelope waveforms is the ADSR envelope. ADSR stands for Attack, Decay, Sustain and Release. Various combinations of these four variables produce unique sounds similar to such instruments as the piano or trumpet. In an electronic music application the composer would combine the necessary fundamentals and harmonics characteristic of a particular instrument and control the output amplitude with an ADSR waveform feeding a voltage controlled amplifier, or VCA. Both the envelope and harmonic content are separate elements of musical compo-

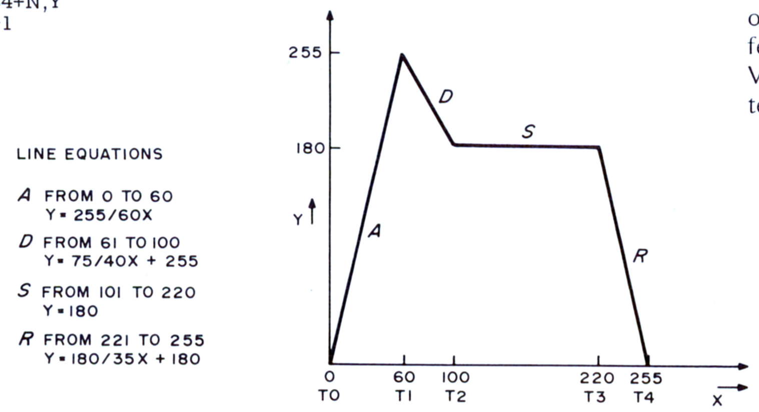


Figure 10: A simple ASDR (Attack, Sustain, Decay and Release) envelope waveform along with the line equations necessary for digital to analog waveform synthesis (see photo 3 and listing 4).

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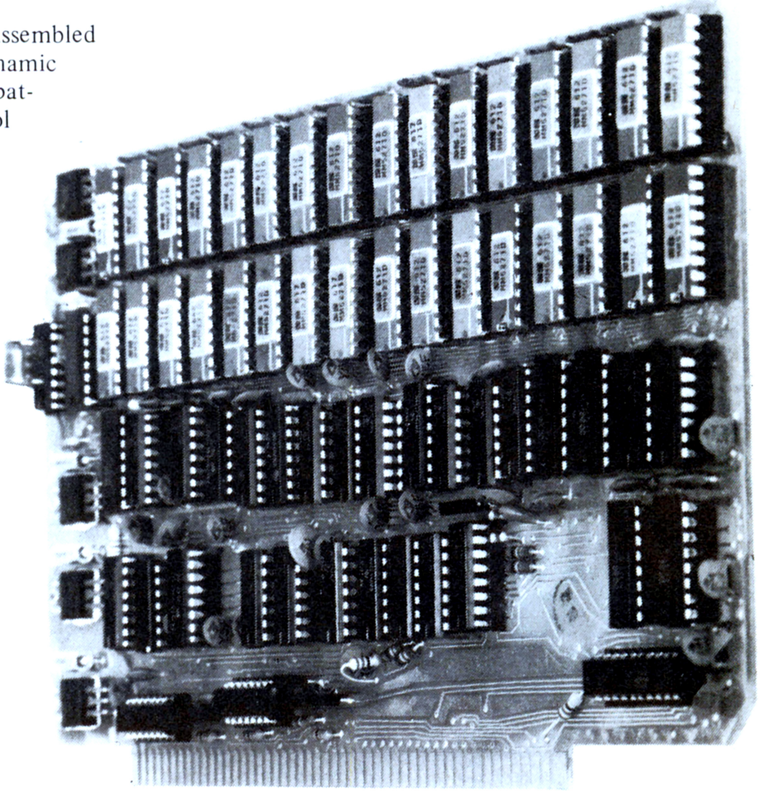

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```
90 PRINT "WAVEFORM BEING CALCULATED"
92 REM THIS PROGRAM CALCULATES THE COORDINATES OF A COMPLEX WAVEFORM
93 REM THE POINTS ARE IN PAGE 100 (OCTAL)
100 LET B=3.14/180*360/256
110 FOR A=0 TO 255
120 LET E=-((255/3.14)*SIN(A*B))
125 LET F=-((255/(2*3.14))*SIN(2*A*B))
130 LET G=-((255/(3*3.14))*SIN(3*A*B))
150 LET Y=INT(127.5+E+F+G)
160 PRINT A,Y
170 FILL 16384+A,Y
180 NEXT A
500 END
```

Listing 5: An extended BASIC program which calculates sample points of the Fourier series illustrated in figure 11 and stores them in a table. Digital Group MaxiBASIC interpreter.

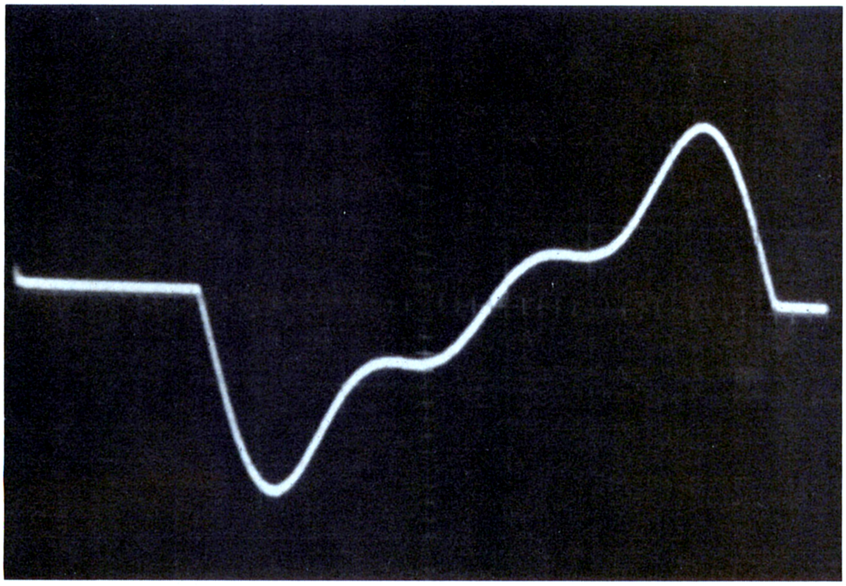

Photo 4: An oscilloscope display of the waveform resulting from the synthesis of a typical complex waveform using the program in listing 5 and the digital to analog converter in figure 9. The waveform is the result of summing three terms of a Fourier series (see figure 11).

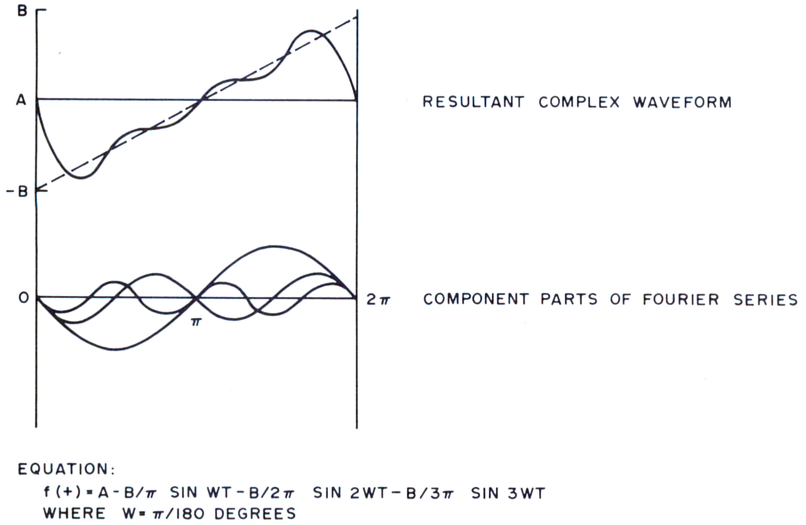
B
A
-B
0
π
2π
RESULTANT COMPLEX WAVEFORM
COMPONENT PARTS OF FOURIER SERIES
EQUATION:
f(+) = A-B/π SIN WT-B/2π SIN 2WT-B/3π SIN 3WT
WHERE W= π/180 DEGREES

Figure 11: A typical complex waveform which is the sum of three terms of a Fourier series. These equations were used by the program in listing 5 to generate the oscilloscope trace of photo 4.

sition. Here they are synthesized separately to illustrate the technique, but mathematically they could be combined into one table. This would impose a far greater limitation on usage than would separate waveforms, but it is not the purpose of this article to investigate electronic music.

The simplest ADSR waveform is composed of four separate linear time dependent functions. Time T = 0 to T_1 is the attack, T_1 to T_2 is the decay, T_2 to T_3 is the sustain, and T_3 to T_4 is the release. Each section is defined by a separate equation and is illustrated by the graph in figure 10. Any waveform which is to be synthesized can be graphed in a similar way.

The four lines in the graph are defined by four equations. These equations, and the beginning and end point limits, can be combined into a BASIC program which creates a table of points. The table is stored in page 100 octal and the display routine is the same as was illustrated in listing 3 (see listing 4 and photo 3).

Real satisfaction comes from mathematically recreating complex waveforms. Synthesis is the combining of parts to form a whole. In Fourier analysis it is the recombination of the terms of the trigonometric series, usually the first four or five, to produce the original wave.

Often it is only after synthesizing a wave that the student is convinced that the Fourier series does in fact express the periodic wave for which it was obtained. This technique of mathematically solving the line equations, loading a point table, and either outputting directly to a plotter or calling a subroutine for an oscilloscope display can prove to be an invaluable education tool to a student involved in advanced math or music courses. Using the digital to analog interface as a Fourier waveform syn-

Note From the Author

This article is an attempt to introduce the computer experimenter to more thought-provoking applications for his or her computer so that the question of its usefulness in the non-industrial environment will seldom if ever be questioned. I'm shortly to begin a regular feature in BYTE on applications systems (hardware and software), and invite correspondence from you, the reader, on possible topics, ideas you would like to see implemented. My address is given at the beginning of this article.

thesizer involves the same point plotting methods as previously outlined, with the exception that the equations become more involved.

Consider the trigonometic series for the complex waveform with a peak amplitude of B=127.5 as illustrated in figure 11.

The Fourier series approximating a triangular waveform can be plugged into an extended BASIC program which calculates the points, while the program in listing 3 can be used to display the tabulation. Photo 4 shows the resulting oscilloscope display.

Conclusions

What started out to be just a simple interface for an analog output can be incorporated into control, music and educational applications. The extent and direction of an experimenter's system expansion is of necessity governed by price performance. This is an inexpensive interface which connects an otherwise isolated digital computer to the analog world. When coupled with a high level language such as extended BASIC, its potential is limited only by the programmer. To think that the home computer is an expensive toy useful only to bide time between monopoly games is equivalent to thinking that a building is only used to hold the sidewalk down.■

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6. Wylie Jr, C R, *Advanced Engineering Mathematics*, McGraw Hill Book Company, NY.

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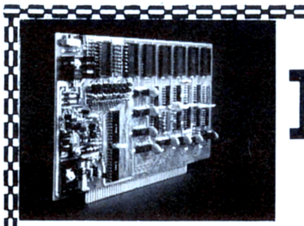

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Member of the ACM and IEEE, and chairman of the 1977 National Computer Conference.
Author of many articles in professional journals and magazines.
Received a Ph.D. in Computer Science from the Southern Methodist University.

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Teacher of electronics and computer programming at a community college
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Director of Computer Products at Heath Company, involved in the planning of new computer products.
Prior to Heath, with McGraw Hill in product planning and design of educational electronic kits.
Prior experience including computer engineering for eight years
Author of several books, home study courses and numerous magazine articles in electronics and computers.
Received a BS in electronics from the University of Houston and a MEd from the University of Maryland

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Carl Helmers . . . Saturday 4 PM and Sunday 4 PM

Editor-in-Chief and co-founder of BYTE magazine.
Obtained computing experience as a personal way to accomplish artistic and technological goals in music.
Graduated in 1970 with a BS in Physics from the University of Rochester, NY.
Worked for several years at Intermetrics, Inc. in Cambridge, Massachusetts on the NASA Space Shuttle Project.
Prior to working with BYTE, publication of a small computer newsletter on a part-time basis.

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How to create music with computers. Problems of performing electronic music, music under computer program control and computer music in conjunction with traditional instruments. Illustrations and examples from personal experience.

Jack L. Davies . . . Friday 8 PM and Saturday 5 PM

President of Pan Atlantic Computer Systems GmbH, a distributor of various micro computer systems in Europe.

Extensive experience in using minicomputers and microcomputers in the US Military Schools in Europe. Designed and developed numerous games and educational programs for students in these schools.

Microcomputers in Education

Discussion of the many possibilities of using microcomputer systems in schools. Effect of personal computers on students.

David Fylstra . . . Saturday 6 PM and Sunday 5 PM

Member of the research staff of the Telecommunications Sciences Center at Stanford Research Institute for more than two years. Specialized in microcomputer software and computer simulation of speech processing systems.

Graduated in 1974 with a BA in English and Psychology, Stanford University, Phi Beta Kappa.

Active in the research on communication systems and devices for the deaf.

Speech Analysis and Synthesis for the Amateur

Using the personal computer as a device to analyze the acoustical foundations of speech and to formulate rules for the control of the speech synthesizer.

Max Mathews Ph.D. . . . Friday 9 PM and Saturday 7 PM

Director of Acoustical and Behavioral Research, Bell Labs

Author of **The Technology of Computer Music,** and numerous articles.

Scientific Advisor to the Institute for Research and Coordination of Acoustics and Music (IRCAM)

Dr. Mathews is often regarded as the "Father of Computer Music"

Pure Digital and Real Time Music Synthesis

The use of the digital computer as a musical instrument with which composers and performers create and play music. Slide and tape demonstration.

Carl L. Holder . . . Saturday 8 AM and Sunday 6 PM

Director of Product Management, Planning and Communications at Information Terminals Corp. for five years.

Prior experience, including Memorex Corp., in the area of magnetic media development and testing.

Present and Future Storage Devices

Survey and discussion of current devices and media, including latest technological developments like the charge coupled devices and magnetic bubble memories. Costs, advantages and disadvantages of these devices for the personal computer user. Accompanied by slides.

DAILY TUTORIALS

There will be two tutorials offered each day, one aimed at those participants who have little or no experience with microprocessors, and the other for those already experienced with microprocessor systems.

BASIC COURSES

1. Development of Microcomputer Systems for Business Use

Sy Ratner, Citibank, N.A.

- system design concepts
- economic efficacy of microcomputers versus large centralized computer systems
- distributed processing definitions
- advantages and problem areas
- network design and architecture
- data communications aspects
- case study: design of a stand-alone workstation for data entry and retrieval

2. Development of Microcomputer Systems for Home Use

Cary Ringel, Con Edison

- survey of simple microcomputer control systems for home use
- selection of hardware: IC's, boards, kits, development systems
- programming and software aids
- interfacing: A/D and D/A conversion
- examples: design of a home control system; microcomputers for a music synthesizer; computer TV games.
- case study: use of the Motorola 6800 in design of a microcomputer system

3. Survey and Comparison of Microprocessors

Donald Lewis, Standard Microsystems Inc. and other speakers

- definitions and distinctions between ALU-chips, controllers, microprocessors, microcomputers
- current applications
- microprocessor architectures (bit-slice, 4-bit, 8-bit, 16-bit, minicomputer-type)
- vendor survey
- performance evaluation and criteria for selection

INTERMEDIATE/ADVANCED COURSES

4. Microprocessor Interfacing

Donald Lewis, Standard Microsystems Inc.

- interface components (peripheral interface chips, UARTS, etc.)
- interface standards (IEEE 488, RE 232C, S-100, etc.)
- interfacing to keyboards
- interfacing to casette and floppy disk drives
- interfacing to display devices
- case study: how to design a CRT terminal

5. Microprocessor Programming and Software

Donald Lewis, Standard Microsystems Inc.

- software design: flow-charting, setting breakpoints, documentation, etc.
- assembly language for the Intel 8080, 8085, Z-80, Motorola 6800
- instruction types and addressing techniques
- use of the stack
- interrupt handling and direct memory access (DMA)
- software development aids
- high level languages for microcomputers

6. Technology Analysis and Forecast of Future Microprocessor Structures

Daniel R. McGlynn, U.S. Philips Corp.
and Will Mathys, MOS Technology Inc.

- emergence of specialized computational elements (SCE)
- architectural evolution (stack processors, reconfigurable architectures, multi-level logic)
- resource management techniques
- software evolution (nano-programming, extensible instruction sets, structured programming modules, very-high-level languages)
- evolution of semiconductor technology of microprocessors
- microprocessor architecture at the chip level
- case studies: design of MOS Technology's new 8-bit and 16-bit processors

Personal Computing Expo to be produced by H.A. Bruno & Associates

H.A. Bruno & Associates, Inc., has been prominent in the exposition and promotion fields since 1923. Highly skilled in the production and promotion of consumer and trade shows, the company currently promotes the American Energy Expo, the National Boat Show, Auto Expo/New York. Promotion assistance also is currently rendered to the National Computer Conference and the Triennial IFIPS Congress in Toronto.

The show producer has promoted successful shows in the New York Coliseum every year since the building opened in 1957. Staff personnel are thoroughly familiar with the building, its services, management and labor.

Interesting, educational exhibits of Personal Micro Computers

The lectures and tutorials are not just theory! You will be able to see a multitude of micro computers. Try out various demonstrations: fascinating games, even in color; small business applications; computer produced speech; music; color graphics; and many more. Micro computers are not only small and portable, also you will need only a "micro budget" to be able to take them home.

Show Hours and Admission

Personal Computing Expo hours are as follows:
Friday, Oct. 28 — Noon to 10 p.m.
Sat. Oct. 29 — 10 a.m. to 10 p.m.
Sunday, Oct. 30 — Noon to 7 p.m.
General Admission: $5.00 (includes free BYTE lectures) per day.
Two-day Tickets: $9.00 (advance sale only)
Three-day tickets: $13.00 (advance sale only)

General Information

You may find it advantageous to purchase two or three-day admission tickets in advance. These are available by mail only, no later than October 10, 1977. Use coupon below.

Group rates (10 or more persons) qualify for $1.00 off regular prices. Arrangements must be made by mail prior to October 10, 1977.

Special arrangements have been made if you desire to stay overnight. Our headquarters hotel, the Barbizon-Plaza, is located on Central Park South, two blocks from Columbus Circle. Single rooms available at $34.00 per night; $40.00 double, plus tax. There's a weekend plan: $22.95 daily, plus tax per person, double occupancy . . . includes breakfast (brunch on Sunday) and meal gratuities. Children under 14 in same room with parents, free.

For hotel reservations and information, call toll free (800) 223-5493. From New York State call (800) 223-5963.

For those traveling to New York by air, American Airlines offers a convenient service through arrangement with Personal Computing Expo. For information, call toll free (800) 433-1790. In Texas the number is (800) 792-1150. From the West Coast, round trip fare via American is only $227.00.

20,000 persons are expected to attend and view the more than 200 exhibits by personal computer manufacturers and retailers.

Personal Computing Expo will occupy the 4th floor of the New York Coliseum. It is located on 59th Street and Columbus Circle — the geographical center of New York City. Garage parking in the building is available.

For answers to any questions pertaining to your attendance at Personal Computing Expo, contact the Show Manager, Ralph Ianuzzi, at Area Code 212/753-4920.

Advance sale of tickets available . . . Three days $13 Two days $9 . . . General Admission $5 MAIL THIS CONVENIENT ORDER FORM NOW!

Personal Computing Expo admission is $5.00 per day. Advance reservation eliminates waiting in line. Order advance tickets with this coupon. Admission ticket includes access to exhibits, lectures and tutorials.

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BYTE's Bits

International Symposium on Minicomputers, Personal and Home Computers

MIMI-77 is the title of a symposium sponsored by the ICORD, IEEE Region 7, and the International Society for Mini and Microcomputers. The dates are November 16, 17 and 18 1977, and the location is Montreal CANADA. The program is divided into two sections. One section covers mini and microcomputer technology and its application; the second section covers personal and home computers. The document we received describing this event was a "call for papers." Persons interested in submission of an abstract for a paper at the conference, or in being placed upon its mailing list, should contact:

Prof J L Houle, MIMI-77
École Polytechnique, Case postale
6079, Succursale A
Montreal, Quebec CANADA
H3C 3A7
Phone: (514) 344-4753■

Dr Iverson's "Thought Experiment" Answered

Last month we published an article by Dr Kenneth Iverson entitled "Understanding APL" (August 1977, page 36), in which readers were challenged to solve the following APL expressions:

```
(2=+/⍉0=(ιN)∘.|ιN)/ιN
```

The answer, which only becomes apparent for N = 7 or greater, is the set of prime numbers from 1 through N! To show how this unexpected result comes about, let us evaluate the expression for N = 7. Since expressions are evaluated from right to left in APL, the first step is to evaluate `ιN`:

```
ιN = 1 2 3 4 5 6 7
```

Next we evaluate everything to the left of the compression operator (/). Expressions in parentheses are evaluated first, so we start with `(ιN)∘.|ιN`), which becomes

```
1 2 3 4 5 6 7 ∘.| 1 2 3 4 5 6 7
```

for N = 7. Performing the residue operation (|), we get:

```
0 0 0 0 0 0 0
1 0 1 0 1 0 1
1 2 0 1 2 0 1
1 2 3 0 1 2 3
1 2 3 4 0 1 2
1 2 3 4 5 0 1
1 2 3 4 5 6 0
```

Before we can transpose this array, we must first perform the "0=" operation:

```
    0 0 0 0 0 0 0
    1 0 1 0 1 0 1
    1 2 0 1 2 0 1
0=  1 2 3 0 1 2 3
    1 2 3 4 0 1 2
    1 2 3 4 5 0 1
    1 2 3 4 5 6 0
```

This gives:

```
1 1 1 1 1 1 1
0 1 0 1 0 1 0
0 0 1 0 0 1 0
0 0 0 1 0 0 0
0 0 0 0 1 0 0
0 0 0 0 0 1 0
0 0 0 0 0 0 1
```

Next, we transpose this array using the transpose operator (⍉). The result is:

```
1 0 0 0 0 0 0
1 1 0 0 0 0 0
1 0 1 0 0 0 0
1 1 0 1 0 0 0
1 0 0 0 1 0 0
1 1 1 0 0 1 0
1 0 0 0 0 0 1
```

Performing the `+/` operation on this array gives:

```
1 2 2 3 2 4 2
```

The expression has thus been reduced to

```
(2=1 2 2 3 2 4 2)/1 2 3 4 5 6 7
```

and this reduces to

```
2 3 5 7
```

This vector is indeed the set of prime numbers between 1 and 7, inclusive. The algorithm works for all integer values of N. (Note that the algorithm excludes 1. If you happen to take the position that 1 *is* a prime number, try writing an APL statement which includes it!)

For readers totally unfamiliar with APL, any of Dr Iverson's many writings on the subject should help. See the references listed in last month's BYTE.■

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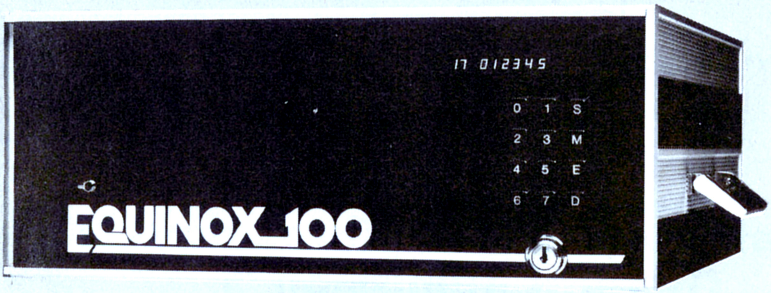

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TSC's Software Catalog. . .

We've received a 1977 catalog from Technical Systems Consultants, Box 2574, W Lafayette IN 47906. While a lot of people have been just talking about the concept, the people at TSC have gone out and done what a growing number of entrepreneurs are doing: publishing and selling software at reasonable prices. The *TSC Software Catalog,* which has a nominal price of 25 cents to cover postage, is available from the company. Most items are sold as completely commented, assembled machine code source listings for the 6800, 8080 or 6502 processor of your system. The prices for typical items from the catalog?

- A BCD floating point package for the 6800 processor is $6.50 for the documentation, plus $3 for a MIKBUG format paper tape.
- A scientific functions extension of the above package runs $10 plus $4 for a paper tape. This gets you transcendentals, and other goodies.
- And of course, the firm will give you a high level language for the 6800 in the form of "Micro Basic Plus" which runs $15.95 for the documentation, plus a paper tape at $6 or cassette tape at $6.95.

The catalog is packed full of numerous items, with most programs written for the 6800 so far (but don't ignore the availability of several 6502 and 8080 packages).

The following quotation from the catalog regarding copyrights and pricing is well worth considering as a philosophy for personal use software marketing:

> *TSC software is among the lowest priced software available to the hobbyist. All prices essentially reflect the cost of documentation and packaging. Why does TSC sell software for so little? The answer is simple: All TSC software is copyrighted, which means it is illegal to make copies of any form. The low pricing is to encourage the hobbyist to buy from us instead of paying close to the same amount for a copy at the local copying machine.*

We heartily agree with this approach, since the world of the personal use computer cannot support the concept of unit sales of custom written hand crafted programming of extremely expensive software. The automobile was a success because of mass production and distribution. Marketing software to lots of people with personal computers requires high volume production at low margin as with any mass market, an enterprise which TSC is proving quite realistic.■

Personal Computing Expo Sets Inaugural NY Show for October 28 thru 30

A major trade and public show, featuring the latest developments and equipment in the fast growing field of personal computing, is scheduled to be held at the New York Coliseum, October 28 thru 30 1977.

The show is called Personal Computing Expo. It will feature an expected 250 exhibitors who will be showcasing their products for the first time in New York City.

There will be speeches arranged by BYTE magazine and the IEEE to fill the seminar agenda, which includes topics for everyone interested in personal computers, from novice to advanced levels. Leading manufacturers have been invited to display and explain their microcomputer systems along with other experts who will conduct forums on algorithms, software, language compilers and assemblers.

Personal design of computers for the more experienced, kit building for the novice, microcomputer applications for business, industry and homes as well as computerized games, vocal output and music are among other topics to be included in the forum.

Persons interested in exhibiting at Personal Computing Expo should contact Ralph Ianuzzi, show manager, H A Bruno & Associates, Inc, 78 E 56th St, NY 10022, (212) 753-4920.■

Computer Shack is Reborn (as "Computerland")

We received the following information from Computer Shack:

Computer Shack Inc, 1922 Republic Av, San Leandro CA 94577, has announced that it plans to change its name to Computerland Corporation. Computer Shack president E E Faber said this action will "strengthen the impact and recognition of the trade name among the consumer public." According to management, franchisees and staff have expressed a strong preference for the "Computerland" name claiming that it better communicates the special nature of this retail computer business. "It avoids the long-range dilution of image that could result from associating high technology quality products and modern store designs with the public's perception of the name Computer Shack," Faber adds.

Computerland Corporation is now operating franchised retail stores in three regional markets: Northern and Southern California and the Atlantic Seaboard.■

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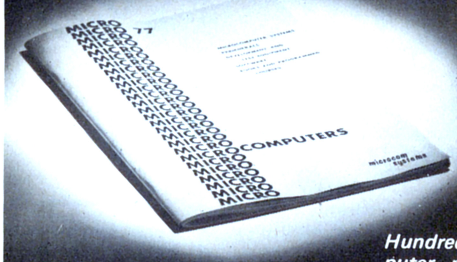

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Continued from page 120

values with the data line and shift clock line, after which the now valid outputs of the n bit shift register can be transferred into the n bit latch to set the state of the valves.

As conceived here, the unit can be directly plugged into an existing parallel output port which has 3 available lines. The timing diagram shown in figure 4 is implemented in software by programming the states of the bits when transferring the current data for the piano, which might be derived from a music interpreter program, or from a real time keyboard source. When programming the low level transfer routine, each bit in turn is shifted and is used to control how the "serial data" line will be set at the output port. After the bit is defined, the "shift clock" bit is turned off, then turned back on, to clock the data into the shift register. After all the control bits have been transferred by "n" operations, the output bit which controls the "transfer clock" line is toggled off, then on, accomplishing the transfer of the shift register's contents to the latches and thus defining the state of the various solenoids.

System Reset and Inhibit

The state of the solenoid drivers must be set in software in the control computer; however, if the system is first turned on, or if garbage is left over from previous use, the result could be a crashing dissonance on the piano output device. To account for bad initial values, the circuit incorporates IC3, which drives the inhibit lines as a set-reset flip flop. When system reset occurs (low level on that line) all the solenoid drivers are disabled by a low level on the "inhibit" input (see figure 3). When the first transfer of data under program control defines a valid solenoid drive state, the inhibit condition is removed by the transfer clock pulse, and does not recur until another system reset.

Summary

In these notes, I have outlined the essentials of the low level details needed to interface a pneumatic player piano with a typical computer system's parallel output lines. This can lead to some very interesting personal use applications of computers, as new piano music is programmed and played using the mass storage facilities of a personal computer instead of the traditional piano roll. These notes are by no means complete, and I leave the software of control of the piano system to the tastes and judgement of the individual user.■

Musical Micros, and More

———**Fingertip Math** from Texas Instruments. The subtitle of **Fingertip Math** reads: "How to use an electronic calculator to put speed, accuracy and confidence into everyday mathematics." It includes chapters on how to use a calculator, reciprocals, powers and roots, number systems, geometric applications, interest and mortgage calculations, and more. **Fingertip Math** is dedicated entirely to applications of the conventional 4 function calculator. Beginnners and professionals alike will find it to be a useful, self-contained tutorial manual. Only $2.95.

Bipolar Microcomputer Components Data Book for Design Engineers
Texas Instruments

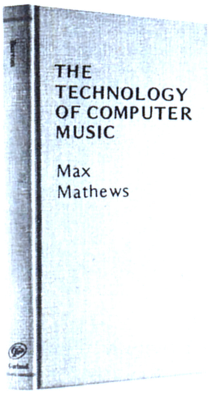
FINGERTIP MATH

———**Bipolar Microcomputer Components Data Book** from Texas Instruments. If you like to build computers from scratch, or are just interested in finding out what is available to the enterprising hacker, Texas Instrument's **Bipolar Microcomputer Components Data Book** is for you. Included are detailed data sheets covering Schottky and Integration Injection Logic (I^2L) 4 bit slice processor elements, plus the SBP9900 16 bit microprocessor. A wide range of bipolar memory components is also covered, as well as bipolar microcomputer support function circuits such as latched bus transceivers, shift registers, programmable logic arrays (PLAs), and so on. With the aid of this handbook, the enterprising experimenter can create a variety of high-powered designs. Only $2.95.

MICROCOMPUTER HANDBOOK
CHARLES J. SIPPL

———**Microcomputer Handbook** by Charles J Sippl. We often hear people say, "I'd like to find out more about microcomputers. I'm not a technical type, but I feel I can handle a fairly rigorous approach as long as it's well-written. What's available?" Charles J Sippl's **Microcomputer Handbook** is one answer to this question. The book covers the present state of computer technology very well, concentrating on both hardware and software. Lucid and complete glossaries are combined with a variety of illustrations. Topics covered include: microcomputers: where they are, what they are doing, and what is next; kits; distributed intelligence; and why the new systems are easier to use. The book was written by a computer industry lecturer and consultant and is highly recommended for the intelligent layman as well as for professionals and experimenters. The glossaries alone are worth the price of the book—don't miss this one! This hardcover reference is only $19.95.

———**The Technology of Computer Music** by Max Mathews, published by the MIT Press. If you're interested in creating music on your microcomputer, here is an excellent source book on the subject written by Max Mathews, often called the "Father of Computer Music." The book includes sections covering the fundamentals of digital sound generation, including the sampling theorem, digital to analog converters, analog to digital converters, filtering, and storage of musical data. A significant portion of the book is devoted to a description of MUSIC V, the well-known high level music language. The sections of the book have been graded so that readers new to the field can approach the material systematically. $16 hardcover.



On the Sensations of Tone
Hermann Helmholtz

———**On the Sensations of Tone** by Herman Helmholtz and published by Dover Publications. This remarkable book is a reprint of the original 1885 edition, reprinted with Dover's usual attention to detail. Despite its age, **On the Sensations of Tone** is still a standard text for the study of the physics and physiology of music. Part 1 explains the sensations of sound in general, vibrations, sympathetic resonances, etc. Part 2 covers combinations of tones and beats. Part 3 concludes the book with Helmholtz's theory of the aesthetic relationships of musical tones. This book will make a valuable addition to the library of anyone interested in the production of music on microcomputers. $6.95.

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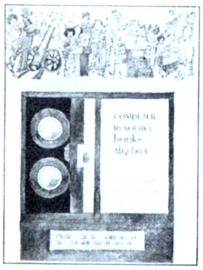
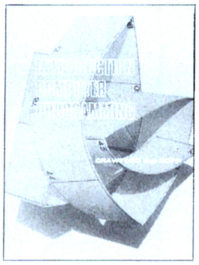
A Bit of the BASIC

———**Computer Resource Book—Algebra** by Thomas A Dwyer and Margot Critchfield is an exciting new way to learn about algebra and the interesting things you can do with it using a computer. The book uses the BASIC language, and flowcharts are used throughout to show the structure of programs. There are 60 applications programs including straight line graphs, polynomial equations, a space probe navigator, temperature profiles, computer generated animation, the ultramatic root finder, random number generation and many more. Although it is particularly suitable for students, just about everyone will find some intriguing and easy to use applications in this entertaining book. $4.80.





———**Introduction to Computer Programming** by Rudd A Crawford Jr and David H Copp. Here is an excellent way to learn about the general aspects of computer programming. **Introduction to Computer Programming** makes use of a hypothetical computer model and set of assembly language instructions designed to help the beginner see what goes on in computer programs. The emphasis throughout is on general principles; such concepts as loops, decisions, flowcharts and IO routines are covered in detail. The book also provides many example problems and prompts the reader by posing several quiz questions. Anyone who masters its contents will have a solid foundation for the study of practical assembly and high level languages. It is especially recommended for students, but just about everyone new to the subject should profit from it. $4.35.

———**Basic BASIC** by James S Coan. If you're not already familiar with BASIC, James Coan's **Basic BASIC** is one of the best ways to learn about this popular computer language. BASIC (which stands for Beginner's All-purpose Symbolic Instruction Code) is easy to learn and easy to apply to many problems. **Basic BASIC** gives you step-by-step instructions for using a terminal, writing programs, using loops and lists, solving mathematical problems, understanding matrices and more. The book contains a wealth of illustrations and example programs, and is suitable for beginners at many different levels. It makes a fine reference for the experienced programmer, too. $7.95.

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AN INTRODUCTION TO COMPUTER PROGRAMMING IN BASIC LANGUAGE
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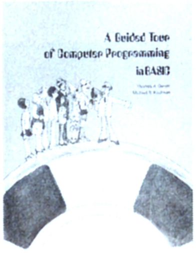
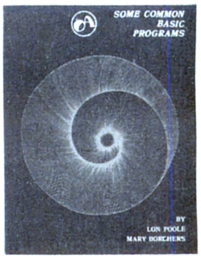
———**Advanced BASIC** by James S Coan. **Advanced BASIC** is the companion volume to James Coan's **Basic BASIC.** In this book you'll learn about some of the more advanced techniques for programming in BASIC, including string manipulation, the use of files, plotting on a terminal, simulation and games, advanced mathematical applications and more. Many useful algorithms are covered, including some clever sorting techniques designed to reduce program execution time. As with **Basic BASIC,** there are many illustrative example programs included. BASIC doesn't have to be basic with **Advanced BASIC**! $6.95.

———**A Guided Tour of Computer Programming in BASIC** by Thomas A Dwyer and Michael S Kaufman. Colorful graphics abound in this lively introduction to the BASIC language. The authors have tried to present a rigorous, yet entertaining approach to the subject. Written for the novice, **A Guided Tour** begins with a section on how to recognize a computer, followed by some tips on working at a terminal. By the end of the book readers are writing their own programs and solving elementary problems in finance and business. The emphasis throughout is on learning by doing. Anyone interested in computer programming should benefit from **A Guided Tour of Computer Programming in BASIC.** $4.80.





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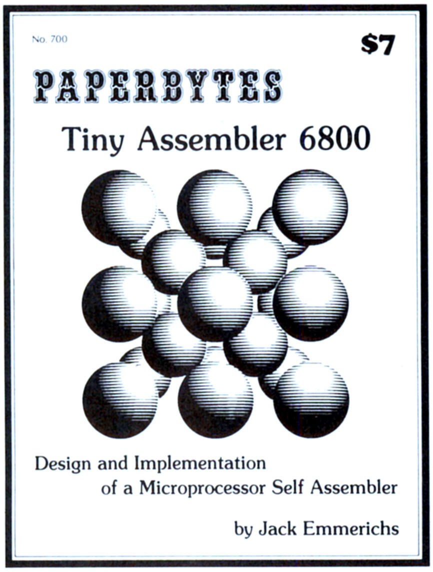

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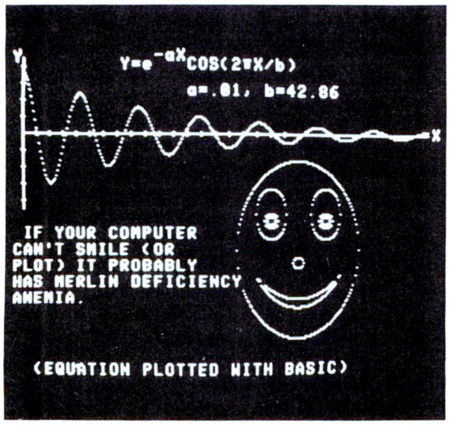
Y=e^{-aX}COS(2πX/b)
a=.01, b=42.86
Y
X
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(EQUATION PLOTTED WITH BASIC)

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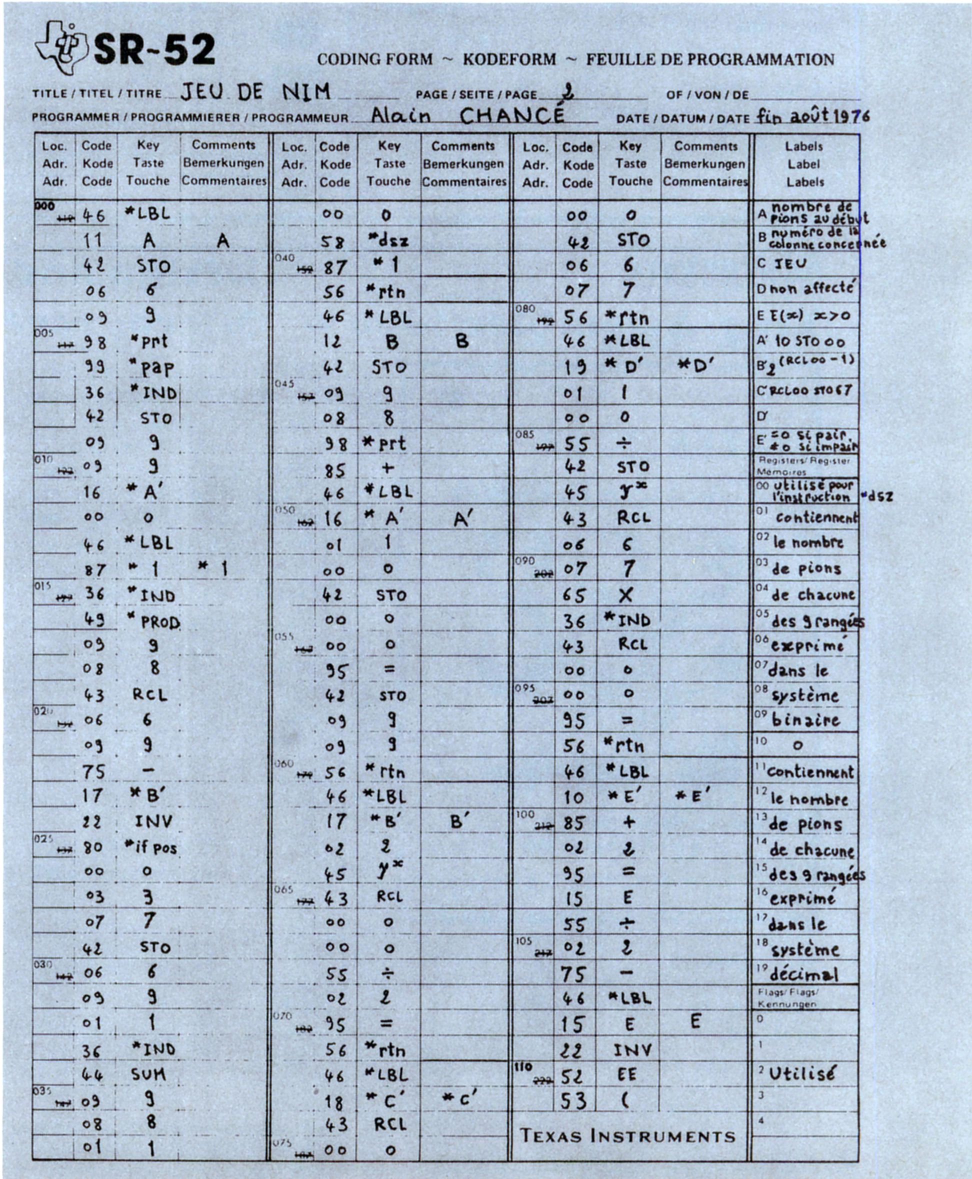
BYTE's Bugs

Super Bug #1

Thanks to inputs from Allen Evans (2 Munsell St, Binghamton NY 13901), Adrian Cammelot (Bell & Howell, Dept 8540, 7100 McCormack Rd, Chicago IL 60645), and several other readers, it became obvious to us that the July 1977 issue of BYTE had a rather important defect in our presentation of "Jeu de NIM, Peut Etre?" by Alain Chancé on page 90. The listing of the TI SR-52 program printed on page 91 included only one half of the total information which came with the article. Presented here then is the complete listing of the program as received with the article. Note that the listing has only two sheets and that these are numbered "2" and "4" in the images printed here, which are photo copies of photo copies of the originals.■



SR-52 CODING FORM ~ KODEFORM ~ FEUILLE DE PROGRAMMATION

TITLE / TITEL / TITRE JEU DE NIM PAGE / SEITE / PAGE 2 OF / VON / DE
PROGRAMMER / PROGRAMMIERER / PROGRAMMEUR Alain CHANCÉ DATE / DATUM / DATE fin août 1976

Loc. Adr. Adr.	Code Kode Code	Key Taste Touche	Comments Bemerkungen Commentaires	Loc. Adr. Adr.	Code Kode Code	Key Taste Touche	Comments Bemerkungen Commentaires	Loc. Adr. Adr.	Code Kode Code	Key Taste Touche	Comments Bemerkungen Commentaires	Labels Label Labels
000	46	*LBL			00	0			00	0		A nombre de pions au début
	11	A	A		58	*dsz			42	STO		B numéro de la colonne concernée
	42	STO		040	87	*1			06	6		C JEU
	06	6			56	*rtn			07	7		D non affecté
	09	9			46	*LBL		080	56	*rtn		E $E(x)$ $x>0$
005	98	*prt			12	B	B		46	*LBL		A' 10 STO 00
	99	*pap			42	STO			19	*D'	*D'	B' $2^{(RCL 00 - 1)}$
	36	*IND		045	09	9			01	1		C' RCL 00 STO 67
	42	STO			08	8			00	0		D'
	09	9			98	*prt		085	55	÷		E' =0 si pair, ≠0 si impair
010	09	9			85	+			42	STO		Registers/ Register Mémoires
	16	*A'			46	*LBL			45	y^x		00 utilisé pour l'instruction *dsz
	00	0		050	16	*A'	A'		43	RCL		01 contiennent
	46	*LBL			01	1			06	6		02 le nombre
	87	*1	*1		00	0		090	07	7		03 de pions
015	36	*IND			42	STO			65	X		04 de chacune
	49	*PROD			00	0			36	*IND		05 des 9 rangées
	09	9		055	00	0			43	RCL		06 exprimé
	08	8			95	=			00	0		07 dans le
	43	RCL			42	STO		095	00	0		08 système
020	06	6			09	9			95	=		09 binaire
	09	9			09	9			56	*rtn		10 0
	75	−		060	56	*rtn			46	*LBL		11 contiennent
	17	*B'			46	*LBL			10	*E'	*E'	12 le nombre
	22	INV			17	*B'	B'	100	85	+		13 de pions
025	80	*if pos			02	2			02	2		14 de chacune
	00	0			45	y^x			95	=		15 des 9 rangées
	03	3		065	43	RCL			15	E		16 exprimé
	07	7			00	0			55	÷		17 dans le
	42	STO			00	0		105	02	2		18 système
030	06	6			55	÷			75	−		19 décimal
	09	9			02	2			46	*LBL		Flags/ Flags/ Kennungen
	01	1		070	95	=			15	E	E	0
	36	*IND			56	*rtn			22	INV		1
	44	SUM			46	*LBL		110	52	EE		2 Utilisé
035	09	9			18	*C'	*c'		53	(		3
	08	8			43	RCL		TEXAS INSTRUMENTS				4
	01	1		075	00	0						

Blackjack Bug

Master Steve Viterwyk of 4402 Meadow Wood Way, Tampa FL 33624, told us at the National Computer Conference show in Dallas TX about his discovery of a small bug on page 150, "SR-52 Card BLACKJACK," line 036, of the June 1977 BYTE. The precent sign should be a division sign. Thanks, Steve.■

A Sour Note in "Sweet Auto Line"

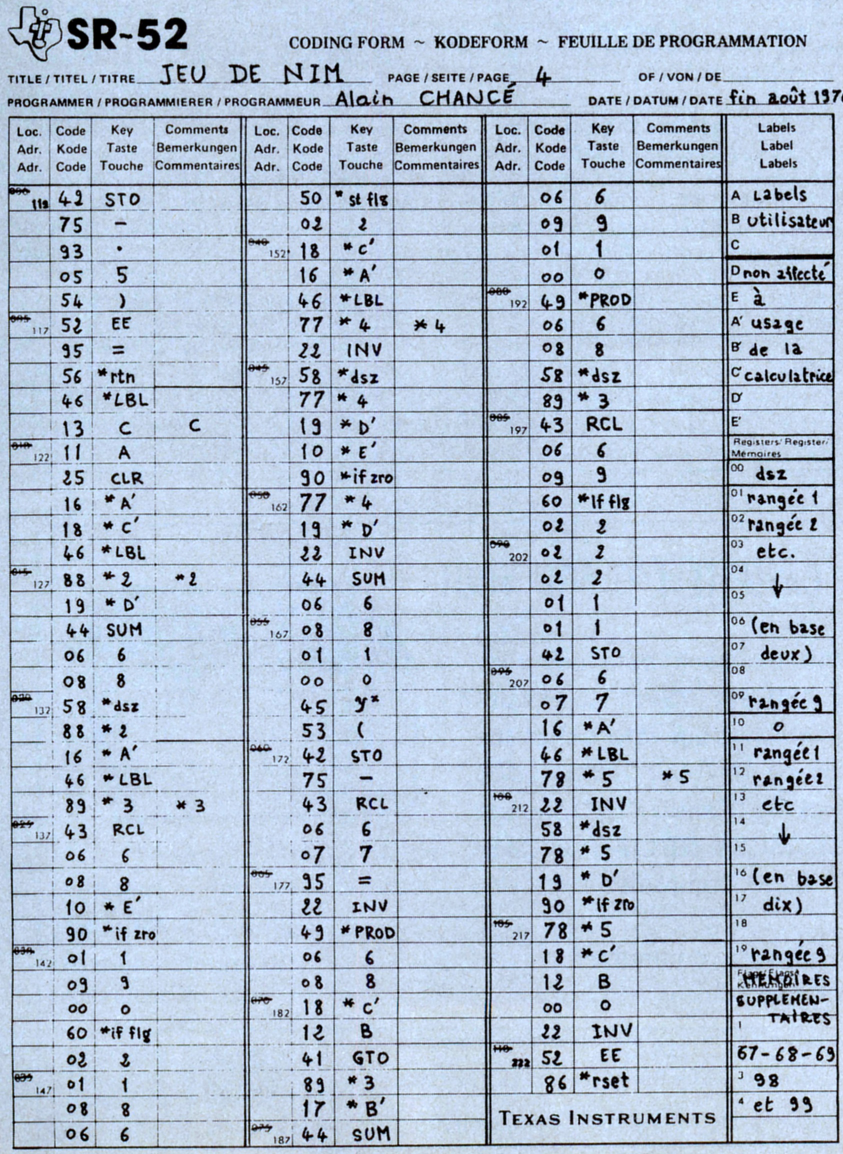
I loved that "Sweet Auto Line" article in your February 1977 BYTE, page 12. Mr Nico is to be congratulated on a job well done. I am anxiously looking forward to future "goodies" comparable to this article.

While working with the information presented in "Sweet Auto Line," I believe I have discovered a slight bug. At the tags ONOFF: AND UNAUTO: reference is made to NEXT-1; I had to use NEXT-2 instead of NEXT-1. NEXT-1 plopped me back in mainline in the middle of an instruction.

If no one else has discovered this bug maybe you can advise everyone in general through an editorial comment.

Walter R Norwood, manager
Computer Hobbies Unlimited
9601 Kendrick Rd
Richmond VA 23235

We've had several other verbal comments by readers, but yours was the first written comment.■



SR-52 CODING FORM ~ KODEFORM ~ FEUILLE DE PROGRAMMATION

TITLE / TITEL / TITRE JEU DE NIM PAGE / SEITE / PAGE 4 OF / VON / DE

PROGRAMMER / PROGRAMMIERER / PROGRAMMEUR Alain CHANCÉ DATE / DATUM / DATE fin août 1976

Loc. Adr. Adr.	Code Kode Code	Key Taste Touche	Comments Bemerkungen Commentaires	Loc. Adr. Adr.	Code Kode Code	Key Taste Touche	Comments Bemerkungen Commentaires	Loc. Adr. Adr.	Code Kode Code	Key Taste Touche	Comments Bemerkungen Commentaires	Labels Label Labels
~~000~~ 112	42	STO			50	* st flg			06	6		A labels
	75	−			02	2			09	9		B utilisateur
	93	•		~~040~~ 152	18	*C'			01	1		C
	05	5			16	*A'			00	0		D non affecté
	54	)			46	*LBL		~~080~~ 192	49	*PROD		E à
~~005~~ 117	52	EE			77	*4	*4		06	6		A' usage
	95	=			22	INV			08	8		B' de la
	56	*rtn		~~045~~ 157	58	*dsz			58	*dsz		C' calculatrice
	46	*LBL			77	*4			89	*3		D'
	13	C	C		19	*D'		~~085~~ 197	43	RCL		E'
~~010~~ 122	11	A			10	*E'			06	6		Registers/ Register/ Mémoires
	25	CLR			90	*if zro			09	9		00 dsz
	16	*A'		~~050~~ 162	77	*4			60	*If flg		01 rangée 1
	18	*C'			19	*D'			02	2		02 rangée 2
	46	*LBL			22	INV		~~090~~ 202	02	2		03 etc.
~~015~~ 127	88	*2	*2		44	SUM			02	2		04 ↓
	19	*D'			06	6			01	1		05
	44	SUM		~~055~~ 167	08	8			01	1		06 (en base
	06	6			01	1			42	STO		07 deux)
	08	8			00	0		~~095~~ 207	06	6		08
~~020~~ 132	58	*dsz			45	y*			07	7		09 rangée 9
	88	*2			53	(			16	*A'		10 0
	16	*A'		~~060~~ 172	42	STO			46	*LBL		11 rangée 1
	46	*LBL			75	−			78	*5	*5	12 rangée 2
	89	*3	*3		43	RCL		~~100~~ 212	22	INV		13 etc
~~025~~ 137	43	RCL			06	6			58	*dsz		14 ↓
	06	6			07	7			78	*5		15
	08	8		~~065~~ 177	95	=			19	*D'		16 (en base
	10	*E'			22	INV			90	*If zro		17 dix)
	90	*if zro			49	*PROD		~~105~~ 217	78	*5		18
~~030~~ 142	01	1			06	6			18	*C'		19 rangée 9
	09	9			08	8			12	B		Flags/ Flags/ Kennungen MEMOIRES
	00	0		~~070~~ 182	18	*C'			00	0		SUPPLEMEN-
	60	*if flg			12	B			22	INV		1 TAIRES
	02	2			41	GTO		~~110~~ 222	52	EE		67-68-69
~~035~~ 147	01	1			89	*3			86	*rset		3 98
	08	8			17	*B'						4 et 99
	06	6		~~075~~ 187	44	SUM						

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Continued from page 10

13(KO), 14(KN), 15(SH), 16(VSS), 17(01), 18(02), 19(EXT), 20(IDLE), 21(IRG), 22(I/08), 23(I/04), 24(I/02), 25(I/01), 26(VDD), 27(VGG), 28(SG), and the pinouts on the TMC0524 which are probably the same as the TMC0523 are: 1(D15), 2(VGG), 3(VDD), 4(I/01), 5(I/02), 6(I/04), 7(I/08), 8(IRG), 9(IDLE), 10(EXT), 11(02), 12(01), 13(VSS), 14(DO), 15(D1), 16(D2), 17(D3), 18(D4), 19(D5), 20(D6), 21(D7), 22(D8), 23(D9), 24(D10), 25(D11), 26(D12), 27(D13), 28(D14).

I know nothing more about the internal structure of the two chips than the pinout names convey except that the TMC0501 is called an "Arithmetic Logic Chip" and the TMC0534 is 13 K word ROM called a "SCOM." I believe it also generates the digit scan pulses and the two phase clock.

I don't think it will help Mr Lewis to write Texas Instruments as I have written and telephoned them and the only information I can get is that the information is confidential. However, that was over a year ago and they may have changed by now.

A company called Bootstrap Enterprises, POB 614, Richardson TX 75080 sells "service manuals" on the SR-50 and SR-52 and they may have one on the SR-51. Their price is $4.50. The data is skimpy but helps and they are prompt.

I am interested in any information which anyone may have on the internal workings of the SR-52.

Incidentally, does anyone know of a MOS or CMOS decade counter with three state BCD output. If so, I'd like its number and manufacturer.

Jack Lambert
5 Graham Rd
Lexington MA 02173

PASCAL PRESSURE

In his article "All This Just to Print a Quotation Mark?" in May 1977 BYTE, page 132, the author offers us a mind bending cure that is worse than the disease. Since the BASIC language he was using did not allow the user to represent a quote within a string delimited by quotes, he created an entire scratch file for the sole purpose of storing a quote which he subsequently read up as a variable and used.

The language I use, PASCAL, features a simple and straightforward solution: a quote mark within a string is represented by a pair of quote marks. Thus, in PASCAL you might say that the problem of quotes is "THE LANGUAGE" "S PROBLEM".

George Cohn
Indiana University
Wrubel Computing Center
Memorial Hall West, Room 013
Bloomington IN 47401

Right you are. But no one has any small computer PASCAL compilers (or interpreters) yet, and when a user has to put up with what he's got, some mind bending contortions may result out of sheer necessity.

COMMENTS ON PASCAL AND STACK MACHINES

The rumor of a Z-200 from ZILOG (April 1977 BYTE, page 140) seems to have triggered a groundswell in the small computer industry (and among personal computer enthusiasts) that cannot be ignored.

The concurrent article (page 128) by Donald J Stavely in your Technical Forum pages adds weight to the concept of using PASCAL (or a PASCAL subset) as a high level language for microprocessor users. The problem, of course, has been core. For example, PASCAL on a PDP 11/45 typically resides in 16 K of 16 bit words and takes seven passes to produce code for an abstract machine. There is an additional overhead of 21 K words for an operating environment.

The ZILOG product, if it exists, would go a long way to bringing the small computer industry to a mature basis by providing it with a structured language. If the Z-200 does not exist the clamour of interest in such a product which your publication has generated must surely bring about its existence.

Keep up the good work, BYTE.

John S Perryn
Hartley Compter Applications Pty Ltd
39 Sherwood Rd
POB 366
Toowong Qld 4066 AUSTRALIA

It turns out that Z-200 (later Z-800) rumor was untrue as of the spring of this year, but Zilog (and other companies) are not resting on past laurels. One design idea we heard at the West Coast Computer Faire from an LSI designer employed by a semiconductor laboratory was the idea of a fairly conventional processor design (at the machine language level) with built-in hooks to higher level functions implemented by fast machine language routines built into a ROM located in the processor. The suggestion was made that such routines could be made to run faster than if they were in external ROM segments due to the lack of any need to go through the external interfaces of the chip, and also due to shortcuts in the addressing of operands. In essence, the concept is one of some "vertical" microprogamming extensions of the instruction set built into the

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design, using the basic instruction set of the processor to implement the functions. As for Zilog, it was the faster Z-80A which was announced this past spring, although representatives of the firm do not deny work upon a machine appropriate for high level language representations of programs. One comment, though, was that it would most likely be a machine which made it easy to generate high level language object code, rather than a design which in any sense could be said to directly execute high level language code.

COMPLAINTS ABOUT BYTE IN THE NUDE.

Now that BYTE is arriving with labels pasted on the cover, I (and probably others) would like to know a simple chemical method of removing the labels.

H W Neff
American Microsystems Inc
3800 Homestead Rd
Santa Clara CA 95051

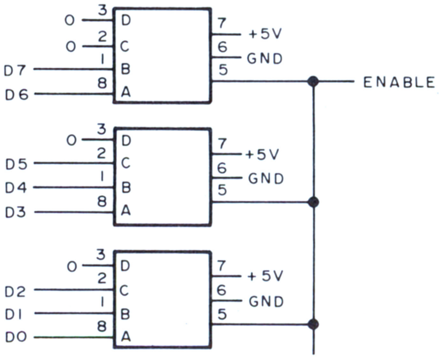
My May issue of BYTE was really messed up in the mail. By coincidence or not, May also happened to be the first issue I got without a wrapper. Is there any way you could put my copy in a wrapper and (hopefully) keep it from being shredded?

J A Beuckman
11889 Creste Verde
St Louis MO 63141

The labels on the cover (May and June 1977) of BYTE were a temporary deviation from standard practice due to the disruptions of a strike at our printer. We like wrappers on magazines as much as you do, and will restore them as soon as possible.

OVERLY PRODUCT ORIENTED?

The LED display as suggested by Mr James Hogenson in his article "Multiplex Your Digital LED Displays" *[March 1977 BYTE, page 122]* seems unnecessarily complicated and expensive, at least for use as a digital readout for a microcomputer. A good alternative would be the use of two (hexadecimal) or three (octal) Hewlett-Packard alphanumeric displays 5082-7300 series. As noted by the attached data sheet, these displays have their own decoder drivers with memory and are DTL and TTL compatible. they can easily be inserted into a small breadboarding socket and hand wired to the bi-directional data bus as follows:



The latch enable should be set to $\overline{\text{OUT}}$ in order to monitor read in and instruction results, and set to ground when single stepping.

Data sheets for the displays may be obtained directly from Hewlett-Packard. J A Titus of Tychon Inc should be credited with researching this product. The displays may be obtained from Schweber Electronics and cost $15.60 per unit.

I would like to take the opportunity to say that your magazine has been a disappointment. Your publication is overly product oriented. In fact, many of your articles are simply reprints of product fliers. How about more emphasis placed on inexpensive computer projects, eg: simple interfacing involving different low priced memories, parallel to serial interfacing, etc?

Also a section devoted to simple software implementation and not necessarily involving BASIC or a high level language would be of interest. An educational series devoted to interested beginners would be helpful. Many of your articles are so difficult to understand that the novice is simply confused.

Considering the rapid advances being made in computer technology, it would behoove the hobbyist with restricted funds to stay with a low cost modular approach with software replacing hardware wherever possible. I think that much of what we see today as being the latest thing in microcomputer products will be obsolete within five years.

Don Woods
12012 Pebblebrook Ln
Carmel IN 46032

You make some good points. But as to "Your publication is overly product oriented. In fact, many of your articles are simply reprints of product fliers," you are out on a proverbial limb sawing rapidly at the nearest node in the root direction. Our articles convey information about the theory and operation of computers, how to build same, designing software, etc. Surely we put in new product releases as well, but that's all part of balancing the complicated equation of customers that is involved in any commerical magazine such as ours. . .CH

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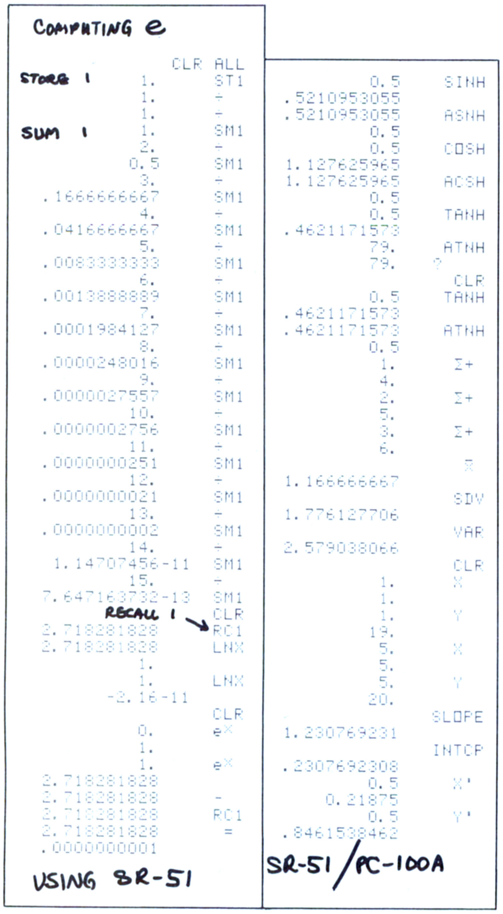
Circle 257 on inquiry card.

MORE HIDDEN GOLD: PC-100 OPERATES WITH SR-51

This letter is in response to that from William D Lewis in June 1977 BYTE. Perhaps I am not the typical BYTE reader because I have acquired over the last several months the Texas Instruments Models SR-51, SR-56, SR-52 and PC-100A. The last is a printer for the SR-56 and SR-52. If one removes the batteries from these calculators, the appearances of the battery compartments are similar (but quite different from that for the SR-50). For all, in addition to the battery terminals, there is a 12 pad connector strip as pictured by Lewis.



```
COMPUTING e

                      CLR  ALL
STORE 1             1.     ST1
                    1.     ÷
                    1.     ÷
SUM 1               1.     SM1
                    2.     ÷
                   0.5     SM1
                    3.     ÷
          .1666666667      SM1
                    4.     ÷
          .0416666667      SM1
                    5.     ÷
          .0083333333      SM1
                    6.     ÷
          .0013888889      SM1
                    7.     ÷
          .0001984127      SM1
                    8.     ÷
          .0000248016      SM1
                    9.     ÷
          .0000027557      SM1
                   10.     ÷
          .0000002756      SM1
                   11.     ÷
          .0000000251      SM1
                   12.     ÷
          .0000000021      SM1
                   13.     ÷
          .0000000002      SM1
                   14.     ÷
       1.14707456-11       SM1
                   15.     ÷
      7.647163732-13       SM1
          RECALL 1 ↘       CLR
          2.718281828      RC1
          2.718281828      LNX
                    1.
                    1.     LNX
            -2.16-11
                           CLR
                    0.     eˣ
                    1.
                    1.     eˣ
          2.718281828
          2.718281828      -
          2.718281828      RC1
          2.718281828       =
          .0000000001

USING SR-51
```

```
                 0.5      SINH
        .5210953055
        .5210953055      ASNH
                 0.5
                 0.5      COSH
        1.127625965
        1.127625965      ACSH
                 0.5
                 0.5      TANH
        .4621171573
                 79.      ATNH
                 79.    ?
                           CLR
                 0.5      TANH
        .4621171573
        .4621171573      ATNH
                 0.5
                  1.       Σ+
                  4.
                  2.       Σ+
                  5.
                  3.       Σ+
                  6.
                            X̄
        1.166666667
                           SDV
        1.776127706
                           VAR
        2.579038066
                           CLR
                  1.        X
                  1.
                  1.        Y
                 19.
                  5.        X
                  5.
                  5.        Y
                 20.
                         SLOPE
        1.230769231
                         INTCP
        .2307692308
                 0.5        X'
             0.21875
                 0.5        Y'
        .8461538462

SR-51/PC-100A
```

I have been tempted for months to put the SR-51 onto the PC-100A just to see what would happen. I was inhibited from this by two facts: The first is that the compartment on the SR-51 is shallow as compared with the others, and second the PC-100A has a 3 position switch marked SR-52, SR-56, "other." After Lewis' letter I said, "I'll do it," and jammed the SR-51 onto the printer. I say "jammed" because it did not go on quite as smoothly as either the SR-56 or SR-52. Naturally I chose the "other" position for the PC-100A selector switch.

The SR-51 is not an "other" device and a next test showed it was not an SR-56. A third trial shows the SR-51 to be an SR-52 as far as the printer is concerned. And, talk about hidden gold, the results were fantastic (see reproduction of a printout). Before I discuss them let me point out that the inner workings of the SR-56 and SR-52 are very different as viewed by the PC-100A and things go to hell if the PC-100A selector switch does not match the calculator.

Texas Instruments is very inconsistent in its various machine features and their modes of operations as compared with those from Hewlett-Packard, thus the SR-51 has many functions not offered on the SR-52 and a few not offered on the SR-56. But, surprise, the PC-100A *knows* about them (unless it is the SR-51 which has more goodies than have been announced). In any case, when the PC-100A is adjusted for the SR-52 but actually gets the SR-51, the printer works as one would hope it would. Actually it works better than one would reasonably expect. One can press the PC-100A PRINT button to print the displayed value at any time, but the operation is most interesting when the PC-100A is in the TRACE mode; here one gets a complete audit trail of all operations and results from operations. The operations printed out include SINH, COSH, SLOPE, INTCP and other functions which *do not even exist* on either the SR-56 or SR-52. Where does this information come from? Will some Texas Instruments engineer please tell us?

The many owners of the SR-51 know that it has the most preprogrammed functions and built-in conversions of all the pocket calculations built by Texas Instruments to the present time. Now that the price for the PC-100A printer is dropping, many of these owners might wish to make a spiffy equipment upgrade by buying one for their SR-51. And, of course, the printer will be usable for a subsequent SR-56 or SR-52. Note: SR-51A might be different from the SR-51.

Webb Simmons
1559 Alcala Pl
San Diego CA 92111

To carry this research further, we need a reader with an SR-51A to try the trick described here. Chances are that the trick will still work, since Texas Instruments probably was consistent in one respect: the design programmers most likly used a common coding scheme for all the arithmetic and transcendental functions of the calculator just to minimize the probability of software error.

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Circle 258 on inquiry card.

June 1977 issue, and no doubt it will trigger a flood of inquiries. All the subscription information was meticulously correct.

But where did the other material come from? We have produced 52 issues to date, with exactly *two* games all told. "Schwartz on Calculators" was one article; hardly a monthly feature. And except for one issue devoted to the Altair, there has never been any information about the micro field. In fact, we rather avoid printing any news at all, with the objective of making our issues sort of timeless. Gee, other than that, everything was correct.

Popular Computing is for people who want to *compute*, and it contains lots of computing problems, articles on how to compute and a series on the Art of Computing.

We'll explain all this to those who write, since we don't want anyone subscribing under a misconception.

Just think of the fun I could have describing BYTE in the same way!

But we do like being mentioned, very much.

Fred Gruenberger
Popular Computing
POB 272
Calabasas CA 91302

Oops! Your letter should correct things a bit.

COPSE OUT

About computers there is no question that the coming of the chip computer heralds a new age. Science fiction writers have long foretold of the personal and personable computer. It is becoming fact. Yet, we who are about to enter the copse must needs reflect upon our passage first, and not as an afterthought.

Your rebuke of Mr Garner's argument, (Ask BYTE, May 1977) was thoughtless and without point. Mr Garner correctly points a finger in the direction of the dike that leaks: our technology. He questions the moral quality of a course of action that is new and untold. And you, obviously lacking an equitable pen, denounce his unspoken ethics only to replace them with your own equally unspoken ethics. Pray tell, from where do you draw your reason, for surely that well is dry?

It can be argued that by any truly human standard of value, computers and robots are not highly desirable technology. I do not argue that human beings are the measure of morality; but I must contend that automation of mental and physical drudgery is not necessarily ethical. If I may, I shall submit an analogy. A man who thinks to build a box might employ a computer to design it, and a robot to build it. The box once complete, though, is not his box. The man never affected the box except to ask for its construction. Effectively he does not understand the box because he did not apply himself to it.

I think (if I may be so bold) that Mr Garner poses this question to each of us. We strive, I no less that others, to produce artificial intelligence. Is it right that this intelligence supplant human intelligence? And is the definition of drudgery to be equated with that of effort? The man who built (euphemistically speaking) the box did not have to reason to build it. His mind was not exercised, nor were his hands. He needed only a rudimentary education and rudimentary expectations to build a box. If he worked in a factory he probably didn't even fully know how to use that wonderful tool which supplanted his own intelligence, and most likely his pride in himself.

In closing I shall ask a question posed once before. Is the definition of drudgery to be equated with that of effort? Take care in your answer, if any, for there are no easy solutions which you might glibly offer.

Nelson E Ingersoll
1620 Carlisle NE Apt C
Albuquerque NM 87110

We'd have a boring world indeed if everything remained constant (and incidentally, regimented) by superstitious fears of the unknown. Progress in technology, good with the bad, is a living manifestation of a viable sentient species, the human race. Attempting to build the dike around technology in the first place is probably one root cause of your metaphorical leak.

I claim it is no less a mark of craftsmanship to give the robot system specifications of one box or many boxes to build than it is to design and build the box by hand; the more versatile person might use either method of construction depending upon mood and ends other than physical creation of a particular box.

COMMENTS ON CERTIFICATION OF TAPES

Judging from David Allen's article on saturation recording, personal computing is about to discover some of the benefits of professional digital recording techniques, of which high storage capacity and faster access time are but a few. Mr Allen may be optimistic, though, in stating the cassette used need not be certified. Of course, an uncertified tape will work if there happen to be no dropouts in a critical area, but are you prepared to trust a laboriously debugged program or critical data to an uncertified cassette? If you can afford to gamble the recovery time and effort against the small additional cost for a certified product it may not matter; but most people, especially those using their systems in a commercial environment, would find the certified cassette well worth the investment. Some of the newer cassette subsystem suppliers, such as Microdesigns, have also discovered the desirability of using a certified cassette. Incidentally, most certified cassettes are usually more

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MODES OF EXPRESSION IN ENGLISH IDIOM

Please don't be intimidated by the likes of Lawyer Welborn, "Windmill Jousting Department" in your June Letters. He's obviously too intelligent to claim that BYTE has no female readers, since that argument could be knocked down by one counterexample, and law school has taught him the fallacy of strict majority rule ("Let's vote on what everybody's favorite color is"), so he resorts to ridicule and appeals to his own definition of reason. But it's easy enough to tell where his heart is when he categorizes your readers as "gals" and "men." Why not "women" and "guys?"

I'll admit that there are places where a simpler construction could be used. For example, in BYTE's Bits, the phrase "the user plays the record on his or her phonograph" could have been tightened up by substituting "a phonograph." But it never struck me that you folks were on any kind of "crusade" (unless that's how you define good manners). All that I've noticed is that yours is just about the only technical publication I can read without wincing every so often.

Carol J Pruitt
1621 18th St NW
Cedar Rapids IA 52405

PATCHING INFO NEED

In your write-up of SwTPC 4 K and 8 K BASIC in the What's New? column on page 72 of January 1977 BYTE, the following sentence appeared: "These packages should work on any 6800 computer system with MIKBUG." I have discovered that the key word in that sentence is "should."

My system is based on a Motorola MEK6800D1 Evaluation Kit with MIKBUG, and neither 4 K nor 8 K BASIC will "play" on it. I have discovered one problem with 8 K BASIC: by changing the instruction at hexadecimal address 0B0D to 7E 0B41, the program jumps around some unwanted PIA initialization routines. Now I can execute the commands and some simple programs, but the IF. . .THEN and FOR . . .NEXT statements, along with most of the functions, don't work.

If anyone has successfully modified SwTPC 8 K BASIC for a Motorola Evaluation Kit I would appreciate hearing from him or her.

Paul E Pennington
1503 Park Av
El Dorado KS 67042

The "should" evaluation was made based on the design of the SwTPC computer system, which has a fairly straightforward adaptation of the Motorola design information. However, as we have found from assembly of an MEK-6800D1, the ROM which comes with that system is for "JBUG," a new monitor which differs from MIKBUG in several key areas.

SR-52 INFORMATION SOURCE

The BYTE readership may be interested to know that there is now an *SR-52 Troubleshooting Guide* available for $12 plus local tax plus $1 shipping from Texas Instruments, POB 53, Lubbock TX 79408.

The artificial intelligence and robotics articles in the past couple of issues were great!

David B Lamkins
DBL Electronics
502-12 Sherman St
Canton MA 02021

ATTENTION AUTHORS: PRESCRIPTION NEEDED

Please get some of your contributors to write a few articles on troubleshooting a nonfunctioning microcomputer. These articles should be pitched to the level of the poor fellow with limited electronic troubleshooting experience who bravely assembled a microcomputer kit only to have it quit working on him. Don't let them say check to see if the assembly was done correctly. The kit documentation already says that. Have them start with the assumption that the assembly has been checked or that the computer was operating and then failed.

Some sample questions that the articles should answer:

- What instruments are necessary and what additional ones are nice to have?
- How does one use the schematics to determine what signals and voltages will be found at various points in the circuits?
- How can one narrow the malfunction down to a particular part of the computer?
- Does one need a stock of replacement parts to use in substitution tests and, if so, how does one determine which ones?

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Receive Channel Frequencies	2025 Hz for space; 2225 Hz for mark.
Transmit Channel Frequencies	Switch selectable: Low (normal) = 1070 space, 1270 mark; High = 2025 space, 2225 mark.
Receive Sensitivity	-46 dbm acoustically coupled.
Transmit Level	-15 dbm nominal. Adjustable from -6 dbm to -20 dbm.
Receive Frequency Tolerance	Frequency reference automatically adjusts to allow for operation between 1800 Hz and 2400 Hz.
Digital Data Interface	EIA RS-232C or 20 mA current loop (receiver is optoisolated and non-polar).
Indicators	Red LED indicates power without carrier. Amber LED lights and red LED goes out upon aquisition of carrier. Data received causes both LEDs to flicker.
Power Requirements	120 VAC, single phase, 10 Watts.
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Circle 260 on inquiry card.

- Is there a burn in time during which one should expect a fairly high incidence of part failure? If so, can one expect the kit manufacturer to replace the parts that failed?
- Where can one go for assistance and advice other than computer club members and the local computer store? Are there any books on the subject?

Buren R Shields
900 Idlewilde Ln SE
Albuquerque NM 87108

A BIT OF A PUZZLE

Does anyone happen to know how it came to be that a "billion" means 10^9 to Americans and 10^{12} to the British, or why Americans and Europeans use "." and "," in opposite fashion when writing numbers?

Jan Kok
126 S Lincoln Av
Loveland CO 80537

INTELLECTUAL AWE

On an intellectual level I am in awe of the creator of the mess pictured on your April 1977 issue. However, if I want to look at junk, I have my own workshop as a source of enjoyment.

Your covers could be a lot better.

Mark H Spohr MD
POB 439
Tahoe City CA 95730

PS: I really enjoy the content of your magazine.

But not everyone has your wide experience, and after all, it was the April cover, was it not?

MORE ON QUOTE KLUDGES

David Chapman's complaint (May 1977 BYTE) about the ugly circumlocution (Is it a kludge if your language processor makes you do it?) required to print a quotation mark is certainly valid. There are, however, better solutions than his suggestion of allowing either single or double quotes as delimiters.

Slightly better is the two for one idea of PL/I. This allows both single (') and double ("") quotes in the same string.

Better yet is the technique used to solve a similar problem in some text editors (see *Software Tools* by Kernighan and Plauger, Addison-Wesley Publishing, Reading MA 01867, 1976). A single character (for example %) is used as an escape throughout the system. Whenever this character occurs, the character immediately following it loses any special meaning. "Therefore, a string can include ',%",%% and even % (carriage-return)." With some cooperation from the keyboard input routines "% (delete-line)" and "% (delete-previous-character)" may be used as data.

This solves many problems which occur when a program produces as its output another program which produces. . .

Moral: People who write software should provide simple yet powerful tools for people who write programs.

Corollary: People who write programs should provide simple yet powerful tools for people who use programs.

Dale Wilson
231 Couch Av
St Louis MO 63122

Ah, but your solution assumes control over the systems software; David's article concerned ways around shortsighted but already implemented systems software which he had access to.

ATTENTION AUTHORS: 2311 DRIVE DATA NEEDED

There have been many articles written about attaching floppy disks to microprocessors and the advantages to be gained from having direct access storage on a microsystem. However from the user's standpoint, floppy disks have possibly two disadvantages: the high cost compared to the cost of the microcomputer, and a relatively small storage capacity.

In the used computer equipment market there are a large quantity of IBM 2311 equivalent disk drives available at bargain prices. These units could offer as much as seven million bytes of direct access storage per spindle depending upon the sectoring approach used. Has anyone investigated the problem of interfacing such a unit to a microprocessor? Perhaps someone has already built such an interface unit.

Any articles on this subject would be greatly appreciated.

Fred W Newton
Manager Data Processing
The Fenton Art Glass Company
Williamstown WV 26187

The 2311 drive has been around for some time due to the widespread use of the IBM System 360 and its cousins. An earlier version with similar media, the 1311 disk drive, should also prove useful to homebrewers.

ARTICLES WANTED

Would appreciate article on use of small computer (Altair 8800b) for routine office tasks such as bookkeeping, payroll, taxes, and also on engineering calculations (lighting, heat loss, heat

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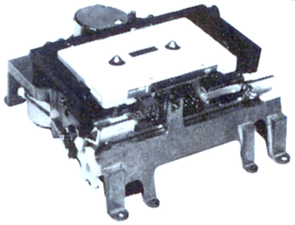

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gain, etc), and especially annual hour-by-hour energy calculations using weather data as input to optimize heating and air conditioning design of buildings. Thanks.

Fred McDavid

ONE POINT DOES NOT A TREND MAKE

I strongly object to your filling issues with articles of a comic or trivial nature. A certain amount of levity is acceptable, but when serious information is ultimately excluded, you cease to be a significant journal and degenerate to the status of trade rag.

Take, for example, your April issue. I immediately object to "Chu Dynasty," "Plexitus," "Arcturus," and "Private Affair." Proceeding to the rest, I see only three articles of interest: "1200 bps Tape," "Baudot," "8008." It may appear that hardware preoccupies my thoughts, and to a degree it does, since your magazine is one of the few sources of beer budget hardware information; of course, good software is not restricted by capital, so anyone can profit from the journals in that regard.

Trevor Hanson
H & D Enterprises
101 Decatur Av
Guilford CT 06437

PIED IN THE SKY?

I have a better origin for the name of the robot in your June 1977 issue "Newt: A Mobile, Cognitive Robot" (by Ralph Hollis, page 30). The lines go:

And I chiefly use my charm
On creatures that do people harm.
The mole and toad and newt *and viper;*
And people call me the Pied Piper.

The author is Robert Browning.

You are the Pied Piper and you do harm by bringing "pied in the sky" articles such as this. I would be happy if I could get a robot to move, much less recognize patterns and play with blocks. As editor of BYTE I would say that your decision to run this article is equivalent to piping Home Computer Town free of hobbyists. Slow-Syn^{TM} bifilar stepping motors indeed!

Mike Rivers
78 Leyfred Ter
Springfield MA 01108

Pied Piper, indeed? What better real world application than mechanisms that move and interact with the environment?

RALPH HOLLIS = TOM PAXTON?

Ralph Hollis obviously had as much fun writing his article, "Newt: A Mobile, Cognitive Robot," [June 1977 BYTE, page 30] as I did reading it.

It's a comprehensive technical piece with some excellent ideas on robotic design. It's also the story of a labor of love. His pictures and descriptions lend the little fellow personality. I chuckled as I read the article, thinking of Tom Paxton's song, "The Marvelous Toy."

The words of this fanciful song, written well over a decade ago, seem to describe Newt. Here is the song; perhaps you'll agree:

When I was just a wee little lad
Full of health and joy,
My father homeward came one night
And gave to me a toy.
A wonder to behold it was
With many colors bright.
And the moment I laid eyes on it
It became my heart's delight.

The first time that I picked it up
I had a big surprize,
For right on its bottom were two big buttons
That looked like big green eyes.
I first pushed one—then the other
Then I twisted its lid,
And when I sat it down again
Here is what it did . . .

It went zip when it moved,
Bop when it stopped,
Whirrrr when it stood still.
I never knew just what it was
And I guess I never will.

It first marched left, then marched right
Then marched under a chair.
And when I looked where it had gone
It wasn't even there.
I started to cry and my daddy laughed
For he knew that I would find,
When I turned around, my marvelous toy
Achuggin' from behind.

Now the years have gone by, too quickly it seems,
I have my own little boy.
And yesterday I gave to him
My marvelous little toy.
His eyes nearly popped right out of his head,
He gave a squeal of glee.
Neither one of us knows just what it is,
But he loves it just like me.

It still goes zip when it moves,
Bop when it stops,
Whirrrr when it stands still,
I never knew just what it was,
And I guess I never will.

Is Ralph Hollis a pseudonym for Tom Paxton, or is Tom Paxton a pseudonym for Ralph Hollis?

J Tom Badgett
1917 Washington St
Bluefield WV 24701

"The Marvelous Toy" by Tom Paxton. © Copyright 1961, Cherry Lane Music Company. Used with permission. All rights reserved. (For interested readers, this song is available on an Elektra recording, The Complete Tom Paxton, *7E-2003.)*

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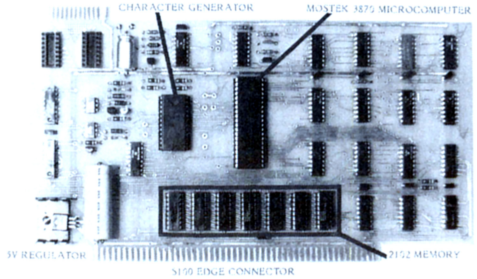

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BYTE. Congratulations! This is one of the finest computer hobbyist oriented magazines I have read to date.

I will come right to the point of this letter. I am looking for a TV monitor that has a 9 inch diagonal screen, perhaps in kit form. I would also be interested in just the CRT and associated electronics so I could design my own terminal cabinet.

All of the monitors (assembled) that I have seen have been over $100. My question is: why buy a $125 monitor and watch nothing but your computer readout, when you could buy a 9 inch TV and get the networks also?

Is there anything that BYTE is aware of that might fill my needs?

Rick Downs
205 Shelton Beach Rd
Apt 53
Saraland AL 36571

Look on page 144 of The Best of BYTE Volume I *(see the BITS advertisement in this issue) for a reprint of Kenneth Barbier's article "The Ignorance is Bliss Television Drive Circuit."*

A LETTER OF THANKS TO RALPH BURHANS AND ASSOCIATES

Many thanks for the series on Omega navigation. I have been experimenting with analog Omega devices for years; now, thanks to your series, I have embarked on a digital version.

I have coded the phase lock loop program for the 6800 already. Currently I am developing a simulator to drive it for test and evaluation. Let's have more on digital radio receivers and coherent CW.

Roy Murphy
System Development Corporation
REM 500
Macara CA 94086

APL CHARACTER GENERATION INTEREST

In reading February 1977 BYTE, I noticed a letter of interest dealing with character ROMs for APL. At the end of the letter, you said something about creating a demand. I'd like to say that I would be willing to purchase two or three such generators, but not five.

Thomas Curley
POB 69
Morrisville NY 13408

A note of interest regarding visual representations: systems with redefinable programmable memory buffer areas for character generation will prove quite useful to APL hackers. Two examples are currently on the market: the Noval computer first seen in BYTE in the June 1977 issue, and the ECD Micromind computer which has been advertised since January of this year. With such redefinable graphics sets, there *is no need to have a ROM at all; one simply creates a table in software with the needed definitions, and changes the definitions "on the fly" if the total number of symbols exceeds the redefinable character generation buffer memory capacity.*

ATTENTION AUTHORS: 16 BIT PROCESSOR INFORMATION NEEDED

I have every issue of BYTE and I feel that it's the best magazine going in the field. I'm presently stationed in Korea, and I repair computers for the Army. I have a delay of a month in receiving my issues, since I have the family send them to me from home. This keeps them from disappearing before I get them, and it gives them an excuse to write. But, to the point.

I find that there is a definite lack of information in the 16 bit processor area. Although there has been a 16 bit chip or two described, the information is very general and, with the exception of the PACE chip, they are hard to find. I prefer to use the PACE chip and associated family of circuits, but any 16 bit chip will suffice.

Examples of information for those wanting a 16 bit system might be:

1. Are there any kits using the 16 bit chips available? */Yes: A system with the Texas Instruments 9900 has been seen in two forms to date./*
2. Since the majority of the peripherals are set up for use with 8 bit processors, can they easily be interfaced with the 16 bit ones? (A logical approach would be to divide the 16 bit word into two 8 bit words, putting the upper half to the device first, then the lower.) */Yes: by emulating the 8 bit bus, as you suggest./*
3. With all the readily available memory for 8 bit processors, can they be used? (Again, with each board using half a 16 bit word?)
4. What software is available? */It varies./*
5. More articles on 16 bit systems are needed, especially those pertaining to the problems of constructing a system.

SP/5 Bernard J Steeves
047-46-6241
169th Sig Co
APO SF 96218

RCA 1802 BASIC WANTED

I am running a homebrew CDP 1802 for which I have not seen an edition of BASIC. If there is such an edition, please let me know.

David Fansler
710 Ward St
Graham NC 27253■

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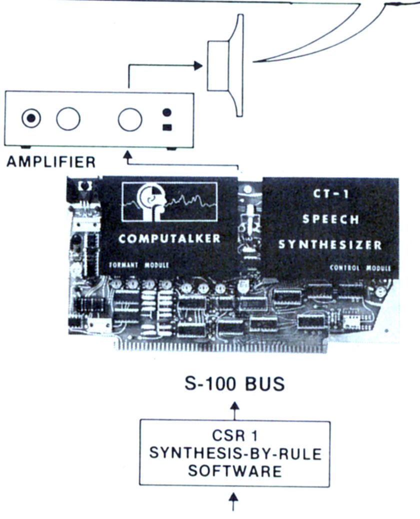

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Continued from page 61

to you. The formulas below will implement their respective functions.

By using the TAN and SQR functions, the sine, cosine, secant and cosecant may be found. The formulas are as follows, with x in radians.

```
SIN(x) = TAN(x)/SQR(1+(TAN(x)**2))
COS(x) = 1/SQR(1+(TAN(x)**2))
SEC(x) = SQR(1+(TAN(x)**2))
CSC(x) = SQR(1+(TAN(x)**2))/TAN(x)
```

Note: could cause a division error when x approaches 0.

From the ATN and SQR function, the Arc-sine and Arc-cosine may be calculated.

```
ASN(x) = ATN(x/SQR(1–x*x))
ACS(x) = ATN(SQR(1–x*x)/x)
```

For values of $x <= 0$, normalize by adding 2π to x.

For still other formulas, try looking in any engineering and math handbook. TAN and SQR can often be found in such books expressed as series approximations which can be expressed even in limited 16 bit integer BASICs. ■

On Finite State Machines and Their Uses

Gerald Owens
POB 9038
Tucson AZ 85720

The two articles by M Wimble in the May and June 1977 BYTEs entitled "Artificial Intelligence, An Evolutionary Idea" provided much food for thought for me, as well as many others I'm sure. If I had a personal computer, I'd try a crack at the earthquake prediction model.

However so much that I hate to dampen anyone's spirits, I must point out a basic limitation to what the system that Wimble outlines has. The implementation is based on what is called a deterministic finite state automation. It's finite, since there are only so many states, and it's deterministic, since when one goes from one state to the next there is no ambiguity or uncertainty as to which state to go to next. Certain properties can be proved about what a finite state automation can do and what it can't do.

First, what it can do. Recurrent patterns are its forte. Given a recurrent pattern, the method Wimble outlines will construct a finite state automaton that will predict what will happen next.

Now, what it can't do. The deterministic finite state automaton cannot recognize, or act upon, all computer languages. You cannot use the method to teach your computer BASIC and expect it to digest your Star Trek program. The language level is of a higher sort than what a finite state automaton can recognize. You should have somebody write up an article on the four levels of grammar, as outlined by Noam Chomsky, and the machines used to recognize sentences in those grammars. I may suggest that there are more fruitful lines of endeavor (like perpetual motion machines or faster than light travel) than teaching a deterministic finite state machine a language. ■

Comments on Floating Point Representation

Sheldon Linker's article on "What's in a Floating Point Package?" *[page 62, May 1977 BYTE]* needs a refinement that might make a difference.

He states that the base of the exponent controls the dynamic range of the arithmetic. What he did not state is that the base also effectively controls the precision. The bigger the base, the greater the dynamic range and the poorer the precision. And this has nothing to do with stealing bits from the mantissa. Choosing the base is not an arbitrary matter of picking a hefty dynamic range.

The problem is illustrated when you attempt to add a single lowest order bit to a mantissa that has all the bits turned on. You can either up the exponent by 1 and renormalize (which is the procedure I read into Linker's article) or you can just not perform the addition. If the exponent is based on 2, then increasing the exponent causes a change in magnitude equal to the change that would be found if a bit were added to any other number. If the base is 16, the change is much greater. The net result is that the precision is much closer to six digits rather than seven.

Another way to look at it is to acknowledge first that all integer arithmetic takes place in finite steps; there are gaps between the numbers. Next, observe that the machine doesn't, through processes unknown, convert over to a continuous number machine when floating point is implemented. With floating point we just get the option of choosing the gap size as well as scaling the numbers.

The difference between base 2 and base 16 may seem trivial to the novice, and indeed must have seemed trivial to enough of the right people at IBM when they went hexadecimal. With base 2 you get seven digits throughout the dynamic range. With base 16 you *seem* to get seven digits most of the time, but are bound to get six now and then. In fact, with 2 and 16 as bases you get four and three digits of precision if your computations have any sophistication (like multiplication and summing) at all. The exact results, of course, depend on the numbers involved, but if you're interested in floating point and want precision, then base 2 cannot be beat. But remember that if you go double precision, then the range will probably be extended and you will have to extend the exponent field.

As an historical note, I heard somewhere that IBM put the exponent up front just to be different from Burroughs or Univac who had the exponent on the right. ■

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Clubs and Newsletters

Conducted by
Peter Travisano

Space Coast Microcomputer Club

The second edition of the *Space Coast Microcomputer Club Newsletter* is out, with an interesting feature by Paul Rainosek, a tabulated comparison of some of the different microprocessor chips available. The various advantages and disadvantages are clearly listed. The comparison includes Intel 8080, Motorola M6800, MOS Technology 6502, Fairchild F8, Signetics 2650, and Cosmac 1801. To find out more about the Space Coast Microcomputer Club contact Ray Lockwood, 1825 Canal Ct, Merritt Island FL 32952.

West Virginia Computer Society

We hadn't heard anything from the West Virginia Computer Society in quite some time. Their newsletter *Oscillations* came in a few days ago to inform us that they are alive and very well at 167 Iroquois Trail, Ona WV 25545.

Indian River Computer Society, Melbourne FL

The Indian River Computer Society meets every Thursday at 7 PM in room 621 of the Science Tower on the campus of FIT, Melbourne FL.

Membership is open to the general public.

For more information call Bill Carter at (305) 773-7837, or Frank Canova at (305) 724-4751, or write: Indian River Computer Society, FIT Electrical Engineering Dept, Country Club Rd, Melbourne FL 32901.

Montreal Area Computer Society

Over the past year the Montreal Computer Society has grown from 12 members to over 90. The club meets once a month, usually on the second Tuesday evening of the month, at Vanier College, 5160 Decarie Blvd. For further information contact John Erikson, the club president at (514) 932-2344 or write: Montreal Area Computer Society, POB 613, Stock Exchange Tower, Montreal, Quebec, CANADA.

Indianapolis Small Systems Group

The Indianapolis Small Systems Group meets on the second Tuesday of each month at the Union Building, Medical Center, IUPUI. Recording secretary T O Whitaker has voiced a strong desire to apply small computers systems to practical business and technical applications. Among such applications is a computerized "newspaper" now under development which would allow the user to receive news over the telephone via a modem. If you have experience with this type of application or would like to find out more about the organization, contact the Indianapolis Small Systems Group at 4719 Squire Dr, Indianapolis IN 46241, or call (317) 241-7396.

IEEE Computer Society

The IEEE Computer Society is one of the most vigorous wings of the Institute of Electrical and Electronics Engineers, the world's largest professional engineering society. *Computer* magazine is published by the computer society; editor and publisher True Seaborn and staff produce this high quality technical magazine every month and cover the microcomputer scene in some detail.

Useful features of the magazine include a monthly column listing all of the new integrated circuits which appear each month from the various manufacturers, and the Repository, a listing of new technical papers about computers. The serious experimenter would do well to consider joining this important organization.

We received the following from Merlin Smith, president of the IEEE Computer Society:

> *The IEEE Computer Society is really a subset of a much larger organization–the Institute of Electrical and Electronics Engineers, whose antecedents reach back into the 19th century and whose history is closely connected with the evolution of electrotechnology in the US. The IEEE, with 180,000 members worldwide, is organized geographically into regions and sections. It is organized by technical interest areas into groups and societies, the largest of which is the Computer Society, with 26,000 members.*
>
> *Like the IEEE, the Computer Society is mainly in the business of dissemination of technical information through conferences, tutorials, workshops, periodicals, and other publications. Its major conferences are COMPCON Spring, held annually in*

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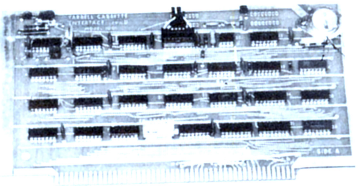

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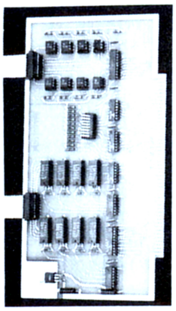

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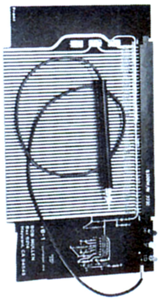

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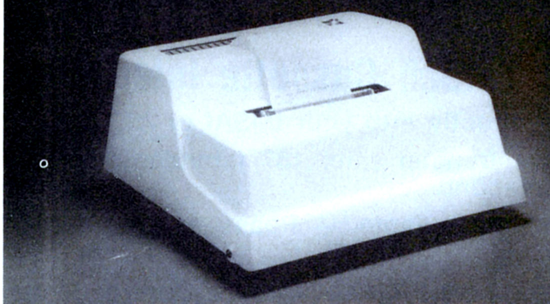

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The Computer Society has chartered some 18 technical committees corresponding to the various technical specialties within the field of computer enginneering. Included among them is the Technical Committee on Minis and Micros, which is of special interest to the personal computing community. The Mini/Micro TC has inaugurated a series of microcomputer workshops (see May Computer*); these likewise may be of interest to your readers.*

The traditional orientation of the IEEE Computer Society has been to the computer designer or the sophisticated computer user, and our membership qualifications entail fairly specific academic and/or professional requirements. However, computers are becoming increasingly "friendly to the uninitiated," and the lines separating the professional from the nonprofessional are tending to blur, at least in some areas. One way for a BYTE reader to find out whether the Computer Society has anything to offer is to pick up a copy of Computer *at one of our conferences or tutorials, at one of our local chapter meetings, or even at the local computer store.*

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Micro-8 Computer Club, Lompoc CA

Micro-8 is a loosely organized, nonhierarchical, extremely enthusiastic group. Originally, it was known as the Central Coast Computer Users Group but recently the name has been changed to perpetuate the memory of the pioneering, now defunct *Micro-8 Newsletter.* The membership includes Hal Singer, former editor of that publication.

Drop in sometime. Visitors are welcome. The club usually has a number of systems on display and lectures by club members are not infrequent.

You can contact Micro-8 at 2497 Lompoc-Casmalia Rd, Lompoc CA 93436, (805) 735-1023. Meetings are held on the third Wednesday of each month at the Cabrillo Computer Center, 4350 Constellation Rd, Lompoc CA, at 7:30 PM.

BAMUG: Bay Area Microprocessor Users Group

The Bay Area Microprocessor Users Group meets on the first Thursday of each month at the Hayward Regional Occupational Center, Hayward CA, at 7 PM.

Like many hobbyist clubs, BAMUG is looking for microcomputer oriented lecturers willing to share their knowledge for little or no fee. Literature from microprocessor manufacturers is especially welcome. Contact BAMUG, 1211 Santa Clara Av, Alameda CA 94501, (415) 523-7396.

Amateur Computer Society of Columbus OH

ACSC meets the first Wednesday of every month at the Center of Science and Industry beginning at 7:30 PM. Dues are $5 per year and include a monthly newsletter *I/O*.

To get in touch with the Amateur Computer Society of Columbus, write: Fred Hatfield K8VDU, Computer Data Systems, 1372 Grandview Av, Columbus OH 43212, (614) 486-3347.

New England Computer Club

New England hobbyists who haven't done so already should investigate the advantages of membership in a first class computer club, the New England Computer Society, or either of its two affiliates, the Southern New England Computer Society and the New Hampshire Computer Society. Contact Robert M Tripp, POB 3, S Chelmsford MA 01824. A newsletter, *The Computerist,* is available at the same address by subscription at $6 per year or 60 cents for a single copy.

Cresent City Computer Club

Cresent City is an active club, sponsoring monthly lectures, classes in BASIC, Assembly Language, and PL/M. The club also includes homebrew and calculator groups. Meetings are held at 8:00 PM at the Science Building, University of New Orleans, second floor, on the second Friday of each month. Write POB 1097, New Orleans LA 70122 or call (504) 722-6321.■

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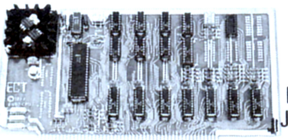

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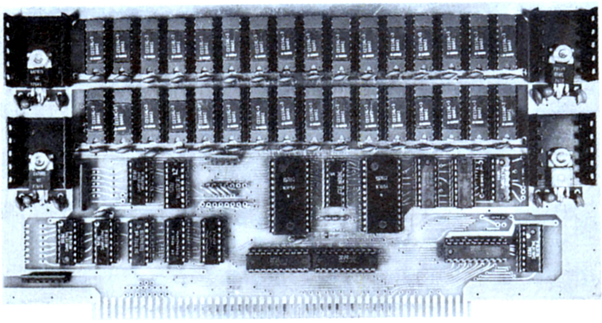

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Walsh Functions:

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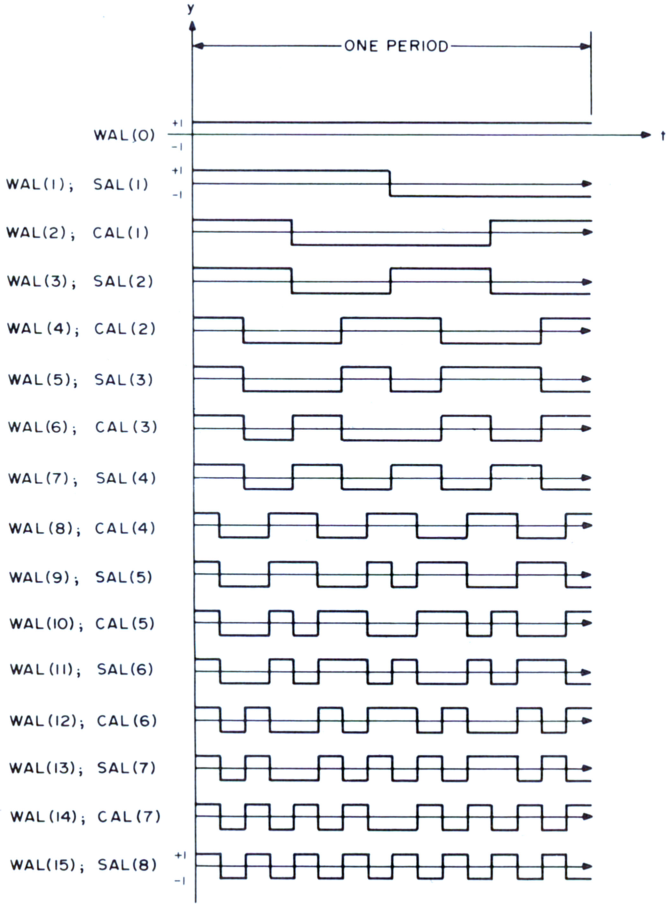


Figure 1: The Walsh Functions WAL(0) Thorugh WAL(15). The fact that Walsh functions lend themselves to digital generation is evident in the nature of the basic wave forms. The notations SAL and CAL emphasize the resemblance of Walsh functions to the Fourier series trigonometric functions SIN and COS.

Using a mathematical technique called Fourier analysis, it is possible to build arbitrary wave forms by adding together various "components."

While a full appreciation of the inner workings of the Fourier series requires a knowledge of advanced mathematics far beyond the capacity of many persons interested in electronics, that in no way deters them from using the concepts or even simplified portions of the math in practical applications. Even beginners are aware that wave forms can be broken into a set of harmonics and that a set of sinewaves of integer multiple frequencies can be summed to build up a complex wave form. In a like manner, Walsh function concepts can be put to work once a few fundamental ideas are mastered. A key to generating complicated sounds in computerized music and voice outputs is the ability to generate arbitrary wave forms from digital codes.

In these days of digital computers, a person familiar with Fourier concepts might ask the question: Is it possible to build up any wave form out of a sum of square waves of some type? Such a system would be ideal for use with digital logic. This question has been answered in the affirmative by the German mathematician H Rademacher, not in 1972 or 1962, but in 1922. His set of square waves, called "Rademacher functions," consists of a fundamental square wave of 50% duty cycle at some frequency

Fourier series are used to create wave forms as the sum of pure sine and cosine waves at selected frequencies; this leads to the obvious question: Is it possible to use a similar mechanism which builds a complex wave form out of digital wave forms with sharp edges?

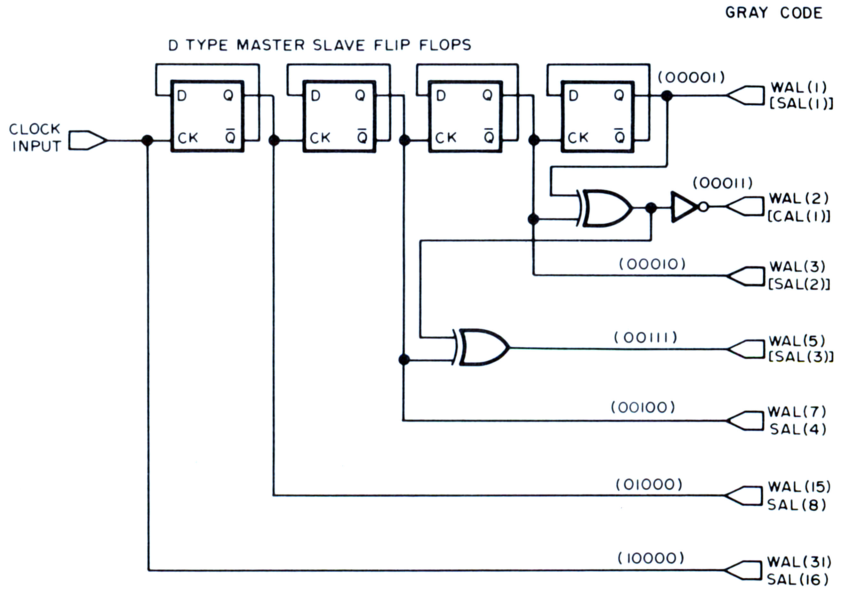


Figure 2: The logic of a digital circuit which generates a set of Walsh functions using a string of flip flops and some external gating. The flip flops are connected as toggles (division by 2 at each stage). The exclusive OR gates combine terms to produce the more complicated Walsh wave forms indicated.

plus harmonics of square waves of 2,4,8,16,32 and higher powers of two times the fundamental frequency. A deficiency of this system, however, is that it is not possible to generate any arbitrary wave shape from only a simple sum of these square wave harmonics.

Also in 1922, J L Walsh presented his independently developed system to the American Mathematical Society. His system was later shown by the Polish mathematician Kaczmarz in 1929 to include the Rademacher system as a subset of the Walsh complete set of orthonormal functions, which, in plain English, says that some of the Walsh functions are square waves and that if all Walsh functions are allowed (you may not need to use them all, however) then any arbitrary periodic wave form can be built up by adding them together in a manner totally analagous to sinewave summation in Fourier series.

Interest in the engineering applications of Walsh functions was sparked by an article in the IEEE *Spectrum* by Dr H F Harmuth of the University of Maryland in 1968 and is continuing because of the suitability of Walsh functions to generation by digital systems.

The fastest way to understand what Walsh functions are is simply to look at a picture of some wave forms. Figure 1 shows the Walsh functions WAL(0) through WAL(15). It is seen that WAL(0) is merely a DC level which we will usually ignore in practical applications since offsets are easily handled by other means and that WAL(1), WAL(3), WAL(7), and WAL(15) are really the square wave Rademacher functions. You will note that in addition to the WAL(n) designation, the functions are also labeled with CAL or SAL. These labels are also commonly used and are acronyms for the terms Cosine wALsh and Sine wALsh by analogy to Fourier analysis. In short all WAL (even n) are called CAL and all WAL (odd n) are called SAL. CAL and SAL are also numbered but the numbers do not correspond to the WAL designation though they are easy to figure out. Also by analogy to Fourier analysis, a Walsh spectrum is called a sequency spectrum as opposed to a Fourier frequency spectrum.

Enter Mr Gray and His Code

However, knowing what Walsh functions look like and knowing how to generate them digitally are two different things. It is clear that the generation of WAL(1), WAL(3), WAL(7), WAL(15), etc, is a snap since they are simple square waves. A string of flip flops does the job, as shown in figure 2. The generation of the remaining functions, while a little more difficult, is not impossibly complex once the mathematics is shaken down into a few simple rules:

1. To generate WAL(n), first write the number n in Gray code. Gray code is a modified binary code having only one bit changing at a time when going to the next higher or next lower number. A table of Gray code numbers is shown in table 1; and with a little

In translating a mathematical summation into a physical circuit, the operational amplifier provides the summing element and the resistors from inputs to the summing node form the coefficients of the component signals.

Walsh functions are the digital answer to sines and cosines used in Fourier analysis.

Table 1: Gray Code Bit Patterns for the Walsh Functions WAL(0) Through WAL(31). The corresponding SAL and CAL notation of each WAL function is shown down the right hand column of the table.

WALSH FUNCTION	DIGIT	WAL(31)	WAL(15)	WAL(7)	WAL(3)	WAL(1)	WALSH FUNCTION
WAL(0)	0	0	0	0	0	0	
WAL(1)	1	0	0	0	0	1	SAL(1)
WAL(2)	2	0	0	0	1	1	CAL(1)
WAL(3)	3	0	0	0	1	0	SAL(2)
WAL(4)	4	0	0	1	1	0	CAL(2)
WAL(5)	5	0	0	1	1	1	SAL(3)
WAL(6)	6	0	0	1	0	1	CAL(3)
WAL(7)	7	0	0	1	0	0	SAL(4)
WAL(8)	8	0	1	1	0	0	CAL(4)
WAL(9)	9	0	1	1	0	1	SAL(5)
WAL(10)	10	0	1	1	1	1	CAL(5)
WAL(11)	11	0	1	1	1	0	SAL(6)
WAL(12)	12	0	1	0	1	0	CAL(6)
WAL(13)	13	0	1	0	1	1	SAL(7)
WAL(14)	14	0	1	0	0	1	CAL(7)
WAL(15)	15	0	1	0	0	0	SAL(8)
WAL(16)	16	1	1	0	0	0	CAL(8)
WAL(17)	17	1	1	0	0	1	SAL(9)
WAL(18)	18	1	1	0	1	1	CAL(9)
WAL(19)	19	1	1	0	1	0	SAL(10)
WAL(20)	20	1	1	1	1	0	CAL(10)
WAL(21)	21	1	1	1	1	1	SAL(11)
WAL(22)	22	1	1	1	0	1	CAL(11)
WAL(23)	23	1	1	1	0	0	SAL(12)
WAL(24)	24	1	0	1	0	0	CAL(12)
WAL(25)	25	1	0	1	0	1	SAL(13)
WAL(26)	26	1	0	1	1	1	CAL(13)
WAL(27)	27	1	0	1	1	0	SAL(14)
WAL(28)	28	1	0	0	1	0	CAL(14)
WAL(29)	29	1	0	0	1	1	SAL(15)
WAL(30)	30	1	0	0	0	1	CAL(15)
WAL(31)	31	1	0	0	0	0	SAL(16)
		GRAY CODE					

So you want to produce a sine wave? Calculate the values at 16 evenly spaced locations in the period, then use these values to calculate the Walsh coefficients using a tabulator method. Then wire in resistors of values derived from the Walsh coefficients and the output of the circuit will be a step function approximation of the desired sine wave.

study, the pattern can easily be extended to any value.

2. Starting with the least significant bit, assign a square wave Rademacher function to each bit. Assign WAL(1) to the LSB, WAL(3) to the next, WAL(7) to the next, etc.
3. Any Rademacher function whose bit is 0 is not used. Those whose bits are 1 are combined by modulo 2 addition, which is to say by exclusive OR gates to give the Walsh output of that order.
4. All Walsh functions must begin positive so that the composite Walsh output may need to be inverted depending upon how many exclusive OR gates were used to produce it.

A couple of examples are shown in figure 2 and a complete generator producing all Walsh functions from WAL(1) through WAL(15) is shown in figure 3.

It should be noted that although a Walsh function is mathematically defined as going from +1 to −1, and it is possible to obtain positive and negative swings with CMOS logic with positive and negative supplies, in practice little is gained by going this route since all that is involved is a DC offset which is easily handled by the summing amplifier. Thus, 0–5 volt TTL logic outputs are fine.

Now that a set of Walsh functions has been generated, it only remains to add them in a summing amplifier with appropriate magnitudes and signs to simulate any wave form with a stair step approximation. The general expression of a Walsh function representation is a summation analogous to that found in Fourier analysis:

$$\text{Arbitrary wave form} \equiv X(t) = A_0 + \sum_{i=1}^{\infty} (A_i .\, SAL(i) + B_i\, CAL(i))$$

where A_i and B_i are weighting constants which correspond to the resistors used in the summing amplifier inputs. The size of the steps and the number present will be determined by how many harmonics are combined. The more you use, the smaller and more numerous the steps, hence the better will be your approximation to your original wave form. The determination of these combining coefficients from the wave form desired requires a bit more detailed consideration.

Wave Form Synthesis

Before proceeding any further into the theoretical aspects of Walsh applications, a review of what we are attempting to do and how we intend to do it will help get our feet on solid ground. The device we wish to build using Walsh functions could be called "a square wave to arbitrary wave form converter." It will be a circuit into which you put a square wave of some frequency and out of which comes a periodic analog signal with a frequency related to that of the input wave (perhaps some submultiple) and a wave form that can be made to take any shape desired by adjusting a set of controls, switches or internal resistors. With such a device, digital logic could be used to synthesize a frequency and the converter could then be set to produce a sinewave for use in standard applications, or given sufficient accuracy of conversion, a computer could be made to talk or even sing. Both have been done by engineers working in this area.

The converter consists of two parts: The first is the digital expander which expands the input square wave into a variety of

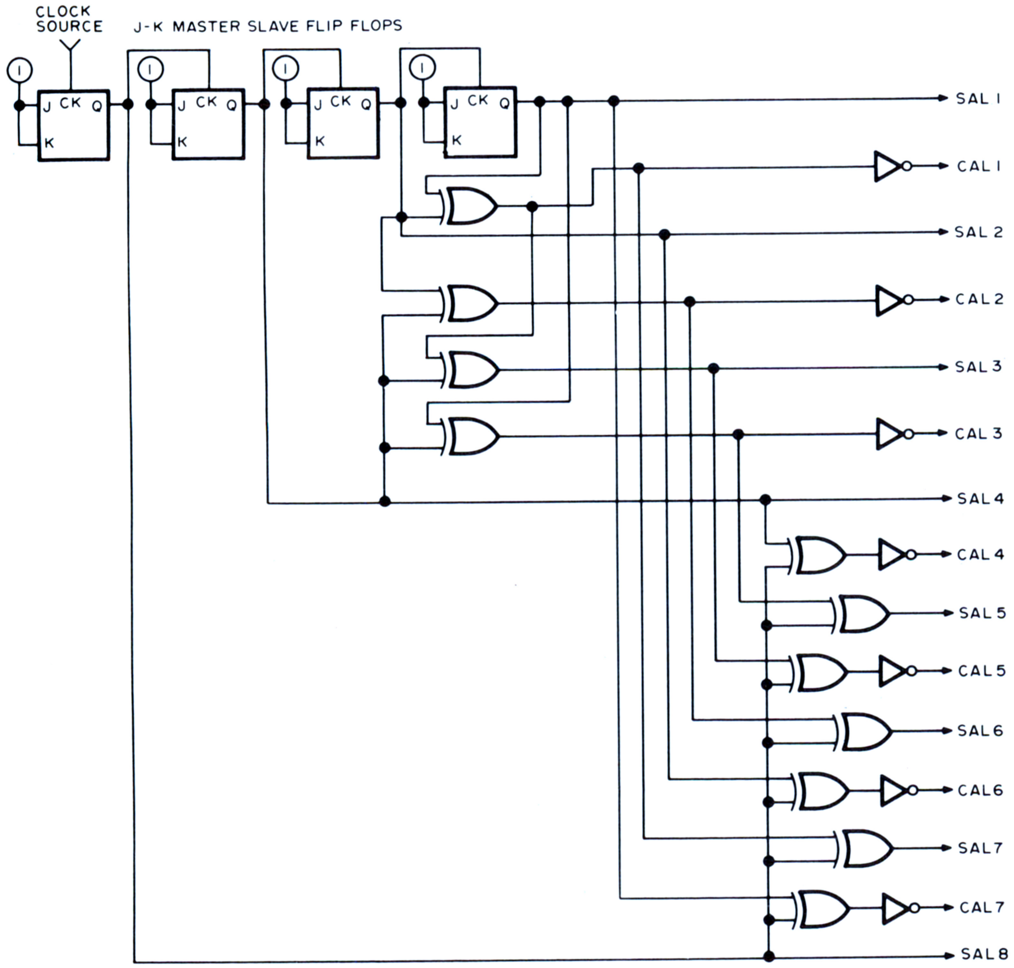


Figure 3: Extending the logic of figure 2, this circuit generates all the Walsh functions WAL(1) through WAL(15) as illustrated in figure 1. This circuit uses an alternate kind of flip flop, the JK master slave flip flop connected as a toggle. This circuit could be built with two 7473 ICs, three 7486 ICs and one 7404 circuit. (One of the 12 exclusive OR sections is used as an inverter.)

digital wave forms, and the second is the analog combiner which adds up these wave forms to produce the periodic analog output. The expander is, of course, the Walsh generator shown earlier and the combiner will be discussed below.

All of the Walsh outputs will be fed into the summing junction of an operational amplifier, but they will not have the same strength or sign. It is the strength and sign of each component which will determine the net analog output so that once we have chosen the analog output we desire, the relative strength and sign of each Walsh harmonic must be calculated from that desired wave form. Once these values are known, a negative sign can be handled with a digital inverter and the magnitude by the choice of the resistor value into the summing junction. The net output will then be a stair step approximation to the desired output which can then be made more perfect by low pass filtering to smooth the wave shape.

Theoretically, the calculation of the coefficients from the analog wave form desired involves complex operations with the integral calculus; but it turns out that it is possible to shortcut the high powered math by starting, not with the analog signal, but rather with the stair step approximating function itself. This function can be easily determined by eyeball or by just taking the height of each step to be the value of the analog output at the center of each time interval. Figure 4 shows two examples: a linear ramp and a sinewave with 16 step approximations. The height of each step is shown.

Before proceeding to an actual calculation we will give some time and work saving rules, which are illustrated in figure 5.

1. The waveform to be synthesized must be repetitive (as in Fourier synthesis), although it is easy to start and stop at any point by control of the digital input.
2. It is especially advantageous to use 2^n steps in one period as this gives an automatic cutoff to the number of Walsh harmonics required

Thus: With a 4 step output no functions beyond WAL(3) are required
" 8 " WAL(7) "
" 16 " WAL(15) " . . .etc.

3. If the coefficients for a higher order

When Walsh function analysis is applied to a linear ramp, what's the result? A set of resistor values which form an ordinary DA converter operating upon the binary value in the counter used for the Walsh function generator.

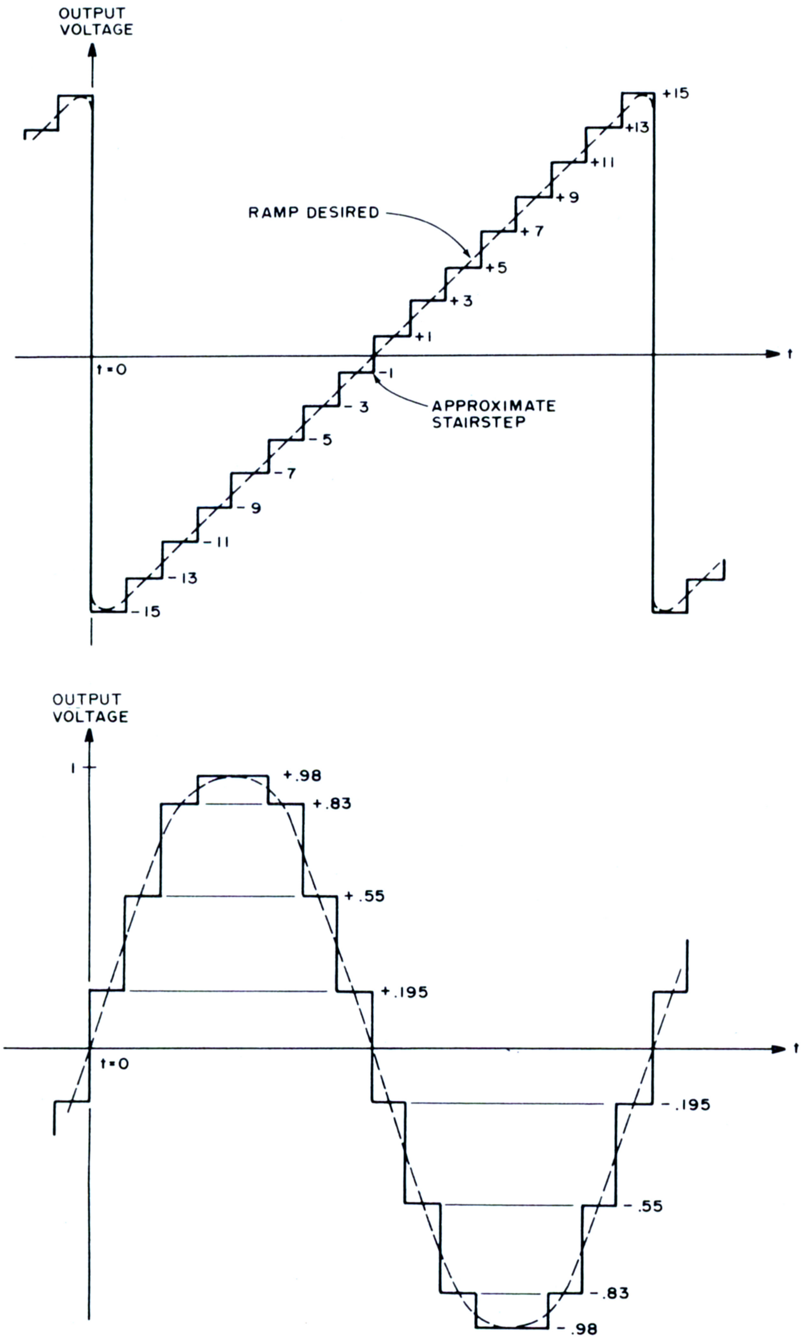


Figure 4: By picking a series of weighting constants for each Walsh function term, the outputs of figure 3 can be summed by an operational amplifier to produce arbitrary wave forms. Here are examples of the ramp and sine wave approximations generated by the Walsh function method. The smooth curve is the desired one in each case, obtained by filtering the output of the summing amplifier.

approximation are calculated (say 16 steps), and a less accurate approximation can be used (say 8 steps) then one only need disconnect WAL(8) through WAL(15) since the lower order coefficients will have the same value in either case (or nearly so). This effect is demonstrated in the sine generator circuit.

If your wave form to be synthesized possesses certain symmetries or can be made to do so by a DC baseline shift, many Walsh component coefficients will be zero which will not only simplify the calculations, but the circuitry as well.

4. If the wave form to be synthesized is even, which is to say that any value that the function takes to the left of center is the same as the value an equal distance to the right of center, then only CAL functions will be used and all SAL coefficients will be zero.
5. If the wave form is odd, or can be made so by a baseline shift, then only SAL functions will be used and all CAL coefficients will be zero. Here any value to the left of center equals minus the value to the right of center.

6A. If the wave form is even as in point 4 above and in addition it is even about the 1/4 point, then only CAL(k) where k is an even number will be present and all CAL(k) where k is an odd number will be zero.

6B. If the wave form is even as in point 4 above and in addition is odd about the 1/4 point, then only CAL(k) where k is an odd number will be present and all CAL(k) with k an even number will be zero.

7A. If the wave form is odd as in point 5 above and in addition is even about the 1/4 point, then only SAL(k) where k is an odd number will be present and all SAL(k) where k is an even number will be zero.

7B. If the wave form is odd as in point 5, and in addition is odd about the 1/4 point, then only SAL(k) with k an even number will be present and all SAL(k) where k is an odd number will be zero.

In the calculations that follow it will also be observed that if a wave form is even or odd, the signed sums of the step values need only be calculated for the first half of the wave form since that value will be exactly half the sum of all steps. This is probably best understood by examining some practical examples.

Two Examples

The first example will be the linear ramp. This function can be made odd by adjusting the baseline, so by rule 5 it is seen that only SAL coefficients need be calculated and no CAL functions need be generated.

The best way to get your mind right in calculating coefficients is to make a table as shown in table 2. The value desired for each step comprising the output function is written in order along the top of the table. Since we are attempting to produce a linear ramp, our output will be a rising staircase with a fixed increase with each step (we used two

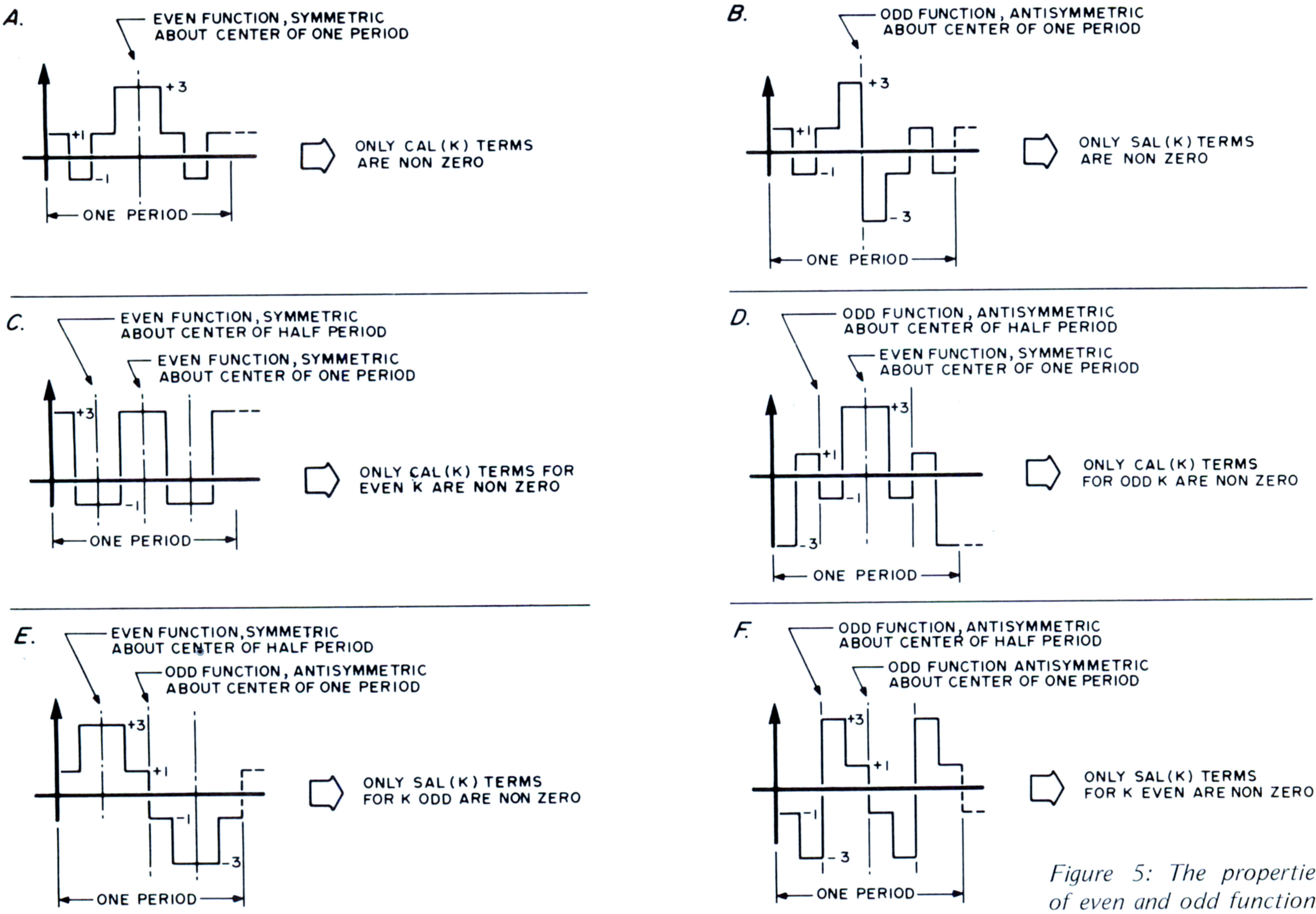

A.
EVEN FUNCTION, SYMMETRIC ABOUT CENTER OF ONE PERIOD
+3
+1
-1
ONE PERIOD
ONLY CAL(K) TERMS ARE NON ZERO
B.
ODD FUNCTION, ANTISYMMETRIC ABOUT CENTER OF ONE PERIOD
+3
+1
-1
-3
ONE PERIOD
ONLY SAL(K) TERMS ARE NON ZERO
C.
EVEN FUNCTION, SYMMETRIC ABOUT CENTER OF HALF PERIOD
EVEN FUNCTION, SYMMETRIC ABOUT CENTER OF ONE PERIOD
+3
-1
ONE PERIOD
ONLY CAL(K) TERMS FOR EVEN K ARE NON ZERO
D.
ODD FUNCTION, ANTISYMMETRIC ABOUT CENTER OF HALF PERIOD
EVEN FUNCTION, SYMMETRIC ABOUT CENTER OF ONE PERIOD
+3
+1
-1
-3
ONE PERIOD
ONLY CAL(K) TERMS FOR ODD K ARE NON ZERO
E.
EVEN FUNCTION, SYMMETRIC ABOUT CENTER OF HALF PERIOD
ODD FUNCTION, ANTISYMMETRIC ABOUT CENTER OF ONE PERIOD
+3
+1
-1
-3
ONE PERIOD
ONLY SAL(K) TERMS FOR K ODD ARE NON ZERO
F.
ODD FUNCTION, ANTISYMMETRIC ABOUT CENTER OF HALF PERIOD
ODD FUNCTION ANTISYMMETRIC ABOUT CENTER OF ONE PERIOD
+3
+1
-1
-3
ONE PERIOD
ONLY SAL(K) TERMS FOR K EVEN ARE NON ZERO

Figure 5: The properties of even and odd functions give constraints on the weighting constants needed for a given wave form. Here are illustrations of six different special cases of symmetry which give zero terms in the Walsh function sum.

units per step). This staircase will eventually be filtered to remove the jogs and give a linear ramp.

The body of the table shows the sign (positive or negative) each particular Walsh function takes in each of the 16 time intervals into which one period of the output wave form has been divided. As indicated earlier, we need not go past WAL(15) in this case. The Walsh sign values can be taken from the wave forms of figure 1 or from table 3 which is good for up to 32 segment approximations.

The numbers to the far right are the sums of the upper values when all signs are taken into account. Thus, for WAL(1) we see that it is positive in the first half period, but the step values are negative, so we get:

(−15) + (−13) + (−11) + (−9) + (−7) + (−5) + (−3) + (−1) = −64 and in the second half period where WAL(1) is negative and the values positive we get:

−(+1) − (+3) − (+5) − (+7) − (+9) − (+11) − (+13) − (+15) = −64 or a total of −128. This number gives the relative strength of WAL(1) in the output summa-

SIGN OF WALSH FUNCTIONS

P = positive N = negative

Normalized Ratio

SAL(1) = −1 = −1
SAL(2) = −0.5 = −1/2
SAL(4) = −0.25 = −1/4
SAL(8) = −0.125 = −1/8

Desired Function Values	ONE PERIOD																Signed Sum
	−15	−13	−11	−9	−7	−5	−3	−1	+1	+3	+5	+7	+9	+11	+13	+15	
SAL(1)	P	P	P	P	P	P	P	P	N	N	N	N	N	N	N	N	−128
SAL(2)	P	P	P	P	N	N	N	N	P	P	P	P	N	N	N	N	− 64
SAL(3)	P	P	N	N	N	N	P	P	N	N	P	P	P	P	N	N	0
SAL(4)	P	P	N	N	P	P	N	N	P	P	N	N	P	P	N	N	− 32
SAL(5)	P	N	N	P	P	N	N	P	N	P	P	N	N	P	P	N	0
SAL(6)	P	N	N	P	N	P	P	N	P	N	N	P	N	P	P	N	0
SAL(7)	P	N	P	N	N	P	N	P	N	P	N	P	P	N	P	N	0
SAL(8)	P	N	P	N	P	N	P	N	P	N	P	N	P	N	P	N	− 16

Table 2: A computational table used to help determine the Walsh function coefficients for the linear ramp. The relative strength of the SAL or CAL term in question is obtained by summing horizontally the +1(P) or −1(N) Walsh function value multiplied by the actual wave form value desired for that element of time. After figuring out the value of the signed sum for each term, the values should be normalized so that the largest magnitude is 1 (regardless of sign). Thus the normalized ratios shown below this picture were computed assuming −128 corresponded to −1.

The Sign of CAL and SAL in Each 1/32 Interval of Their Period

WAL(0)	PPPP	PPPP	PPPP	PPPP	PPPP	PPPP	PPPP	PPPP
SAL(1)	PPPP	PPPP	PPPP	PPPP	NNNN	NNNN	NNNN	NNNN
CAL(1)	PPPP	PPPP	NNNN	NNNN	NNNN	NNNN	PPPP	PPPP
SAL(2)	PPPP	PPPP	NNNN	NNNN	PPPP	PPPP	NNNN	NNNN
CAL(2)	PPPP	NNNN	NNNN	PPPP	PPPP	NNNN	NNNN	PPPP
SAL(3)	PPPP	NNNN	NNNN	PPPP	NNNN	PPPP	PPPP	NNNN
CAL(3)	PPPP	NNNN	PPPP	NNNN	NNNN	PPPP	NNNN	PPPP
SAL(4)	PPPP	NNNN	PPPP	NNNN	PPPP	NNNN	PPPP	NNNN
CAL(4)	PPNN	NNPP	PPNN	NNPP	PPNN	NNPP	PPNN	NNPP
SAL(5)	PPNN	NNPP	PPNN	NNPP	NNPP	PPNN	NNPP	PPNN
CAL(5)	PPNN	NNPP	NNPP	PPNN	NNPP	PPNN	PPNN	NNPP
SAL(6)	PPNN	NNPP	NNPP	PPNN	PPNN	NNPP	NNPP	PPNN
CAL(6)	PPNN	PPNN	NNPP	NNPP	PPNN	PPNN	NNPP	NNPP
SAL(7)	PPNN	PPNN	NNPP	NNPP	NNPP	NNPP	PPNN	PPNN
CAL(7)	PPNN	PPNN	PPNN	PPNN	NNPP	NNPP	NNPP	NNPP
SAL(8)	PPNN	PPNN	PPNN	PPNN	PPNN	PPNN	PPNN	PPNN
CAL(8)	PNNP	PNNP	PNNP	PNNP	PNNP	PNNP	PNNP	PNNP
SAL(9)	PNNP	PNNP	PNNP	PNNP	NPPN	NPPN	NPPN	NPPN
CAL(9)	PNNP	PNNP	NPPN	NPPN	NPPN	NPPN	PNNP	PNNP
SAL(10)	PNNP	PNNP	NPPN	NPPN	PNNP	PNNP	NPPN	NPPN
CAL(10)	PNNP	NPPN	NPPN	PNNP	PNNP	NPPN	NPPN	PNNP
SAL(11)	PNNP	NPPN	NPPN	PNNP	NPPN	PNNP	PNNP	NPPN
CAL(11)	PNNP	NPPN	PNNP	NPPN	NPPN	PNNP	NPPN	PNNP
SAL(12)	PNNP	NPPN	PNNP	NPPN	PNNP	NPPN	PNNP	NPPN
CAL(12)	PNPN	NPNP	PNPN	NPNP	PNPN	NPNP	PNPN	NPNP
SAL(13)	PNPN	NPNP	PNPN	NPNP	NPNP	PNPN	NPNP	PNPN
CAL(13)	PNPN	NPNP	NPNP	PNPN	NPNP	PNPN	PNPN	NPNP
SAL(14)	PNPN	NPNP	NPNP	PNPN	PNPN	NPNP	NPNP	PNPN
CAL(14)	PNPN	PNPN	NPNP	NPNP	PNPN	PNPN	NPNP	NPNP
SAL(15)	PNPN	PNPN	NPNP	NPNP	NPNP	NPNP	PNPN	PNPN
CAL(15)	PNPN	PNPN	PNPN	PNPN	NPNP	NPNP	NPNP	NPNP
SAL(16)	PNPN	PNPN	PNPN	PNPN	PNPN	PNPN	PNPN	PNPN

← 1 Period →

P = Positive N = Negative

(Columns only for ease of reading.)

Table 3: A larger computational table giving 32 Walsh function components and their signs during a 32 interval period.

	SIN(11.25°) = 0.19509	SIN(33.75°) = 0.55557	SIN(56.25°) = 0.83147	SIN(78.75°) = 0.98708	SIN(101.25) = 0.98708	SIN(123.75) = 0.83147	SIN(146.25) = 0.55557	SIN(168.75) = 0.19509	signed sum	Normalized coefficients = A_i
SAL(1)	P	P	P	P	P	P	P	P	−5.1258	−1
SAL(3)	P	P	N	N	N	N	P	P	+2.1232	+0.4142
SAL(5)	P	N	N	P	P	N	N	P	+0.4223	+0.08239
SAL(7)	P	N	P	N	P	N	P	N	+1.0196	+0.1989

← 1/2 period →

Table 4: Using the computational table to calculate the resistor values for a 16 step sine wave approximation. The specialized sine wave generator of figure 6 uses these results, subject to a further approximation shown in table 5.

tion. We repeat the process for each Walsh function.

If we divide all nonzero values by the largest (WAL(1)), it is observed that the weighting is binary and further it is seen that only the square wave Rademacher functions are nonzero. Thus, it is seen that the way to generate a ramp is with a counter feeding a standard digital to analog converter. (So here we have a long, complicated way of arriving at an "obvious" result, but it also should be noted that D to A binary weighting is *only* "matched" to a ramp output.)

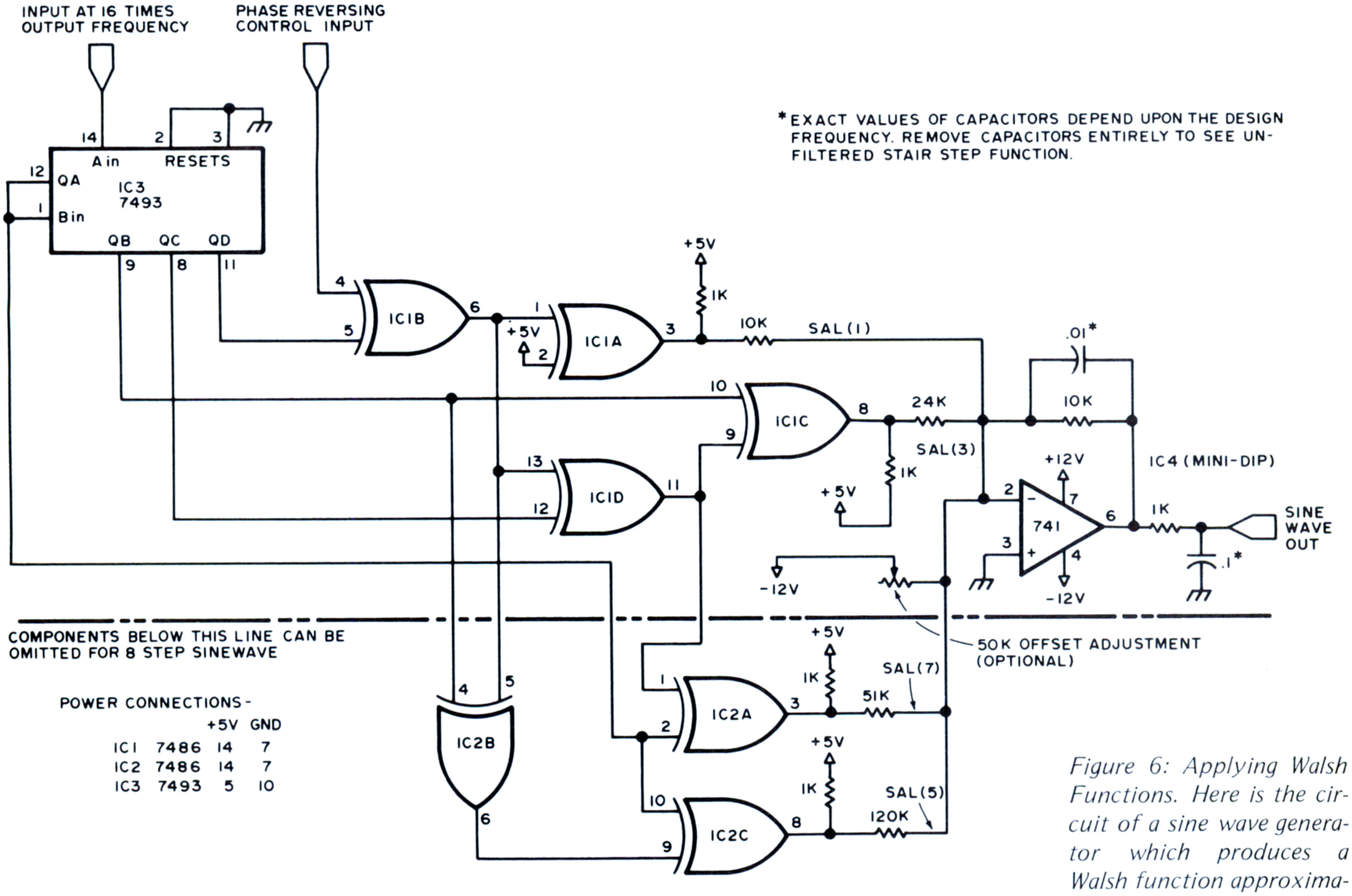
If another wave form such as a sinewave is desired, a D to A converter could be used, but a more accurate method would be to switch between 16 voltages of appropriate values. The Walsh system is just as accurate and is simpler for the more general case.

If we divide a sinewave into 16 portions, the value at the center of the first interval will be Sin (11.25°) = 0.09802 and the next will be Sin (33.75°) = 0.55557 and the next Sin (56.25°) = 0.83147, etc. This produces the top row of our table. Since Sin(x) is an odd function, even about the 1/4 point, only SAL(1), SAL(3), SAL(5) and SAL(7) are calculated over the first half period. Our chart with the calculated coefficient values is shown in table 4. Since in a standard operational amplifier summing circuit (we won't go into details here as they can be found in any book on operational amplifiers), the relative summing ratios are related to the inverse of the summing resistor values, we divide each normalized value into 1 and multiply by the feedback resistor value to obtain each summing resistor value in ohms. Table 5 shows the calculated values compared to 1% and 5% EIA resistor standard values.

The total sinewave converter circuit is shown in figure 6. While three of the coefficients were negative, a single inverter was used on the lone positive Walsh output since the op amp inverts the wave form. In addition, a gate has been added by which the phase of the entire output wave form can be

$\frac{1}{A_i}$ x 10k	1%	5% EIA
10.00k	10.0k	10k
24.14k	24.3k	24k
121.4 k	121 k	120k
50.27k	49.9k	51k

Table 5: The EIA resistor equivalents for the calculated values of table 4. The 5% tolerance resistance values shown at the right were used in the circuit of figure 6.


INPUT AT 16 TIMES OUTPUT FREQUENCY
PHASE REVERSING CONTROL INPUT
*EXACT VALUES OF CAPACITORS DEPEND UPON THE DESIGN FREQUENCY. REMOVE CAPACITORS ENTIRELY TO SEE UNFILTERED STAIR STEP FUNCTION.
14
2
3
12
1
A in
RESETS
QA
IC3
7493
Bin
QB
QC
QD
9
8
11
4
5
IC1B
6
1
+5V
2
IC1A
3
+5V
1K
10K
SAL(1)
.01*
10K
10
9
IC1C
8
24K
SAL(3)
1K
+5V
+12V
IC4 (MINI-DIP)
13
12
IC1D
11
2
3
741
7
6
4
1K
SINE WAVE OUT
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-12V
-12V
COMPONENTS BELOW THIS LINE CAN BE OMITTED FOR 8 STEP SINEWAVE
+5V
50K OFFSET ADJUSTMENT (OPTIONAL)
POWER CONNECTIONS -
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IC2 7486 14 7
IC3 7493 5 10
4
5
IC2B
6
1
2
IC2A
3
1K
SAL(7)
51K
+5V
1K
SAL(5)
120K
10
9
IC2C
8

Figure 6: Applying Walsh Functions. Here is the circuit of a sine wave generator which produces a Walsh function approximation of the sine function. The frequency of the sine wave is set by the input to pin 14 of the 7493. Filtering components of the operational amplifier help smooth out the staircase wave form generated by summing the Walsh function components as weighted by resistors.

inverted by simultaneously inverting all Walsh components. It is interesting to also note that if the components below the dotted line are removed, an 8 step sinewave approximation results. The feedback capacitor and output low pass filter can be added to smooth up the wave form to give a nearly perfect sinewave.

The Walsh methods presented here would seem to have wide application for experimentation and engineering. Although these concepts are based on advanced mathematics, nevertheless, as the philosopher Seneca observed so many years ago, "The language of truth is simple."

Walsh Functions for Music Synthesis?

Some background information on the use of orthogonal functions in music wave form synthesis has been generated by Hal Chamberlin, and published in *Electronotes Newsletter*, Volume 4, Number 25, July 20 1973. Hal also sent along a copy of a portion of a report by B A Hutchins, 60 Sheraton Dr, Ithaca NY 14850, on the use of Walsh functions in wave form generation. According to Hal, there was considerable analysis of Walsh functions in electronic music circles during a period of time approximately centered on 1973, but complexities of controlling the Walsh harmonic amplitudes digitally led to the demise of that interest. Hal's current approach is to employ a real time Fourier series evaluation module which digitally sums terms of the first 32 components of a Fourier series, specified to 8 bit accuracy both in amplitude and phase.

GLOSSARY

The following terms may be unfamiliar to some readers and are highlighted with further explanations.

Baseline: It is possible to add a fixed DC level to an analog signal, which will not affect its wave form. Using the 0 V and +5 V levels obtained with TTL circuits (using pull up resistors) as "Walsh functions" corresponds to a baseline adjustment of +2.5 volts to the ideal case of a symmetric positive or negative voltage value.

CAL: An acronym derived from Cosine wALsh. The CAL functions are the "even" Walsh functions, analogous to the Fourier cosine functions.

Duty cycle: For a digital wave form, the duty cycle is the percentage of time spent in the high state relative to the full period of the wave form.

Even function: An even function (or wave form) is one which is symmetric about the center point of its period. This means that its value a certain distance to the left of center is the same as its value the same distance to the right of center.

Fundamental: The lowest frequency in a Fourier or Walsh function summation.

Gray code: A binary code modified so that only one bit changes when going to the next higher or lower number. It is often used to deglitch position encoders.

Harmonic: A frequency which is a multiple of the fundamental frequency.

Integral calculus: The mathematical formalism used to calculate the area under a curve. The integral calculus is used together with the theory of orthogonal functions to evaluate analytically the coefficients of Fourier and Walsh function expansions. The example of Walsh function coefficient calculation in this article uses properties of Walsh functions to simplify the process of calculating integrals required for the coefficients. There is no such simplification for the Fourier coefficients of a wave form, thus making the application of Fourier analysis a more complicated problem.

Odd function: An odd function (or wave form) is one which is antisymmetric with respect to the center point of its period. This means that if at a fixed interval before the center point its value is X, then at the same interval past the centerpoint the value will be −X.

Orthonormal functions: The mathematical theory of orthonormal functions is one of the most powerful tools used by physicists, theoretical chemists and engineers. Among other applications, it provides the tools needed to analyze complex wave forms and synthesize such wave forms using the principle of superposition: That the whole is a linear sum of its parts. Fourier series and Walsh function analysis mentioned here are two particular choices of a set of orthonormal functions which have useful practical applications. (See also **spectrum** below.)

Periodic wave form: A periodic wave form is one which has a fixed shape which is constantly repeated. A simple example would be the clock oscillator signal of a typical home brew central processor. A more complicated example (subject to imperfections) would be a long steady tone played on a musical instrument.

Rademacher functions: The subset of Walsh components consisting of only the unmodified square waves.

SAL: An acronym derived from Sine wALsh. The SAL functions are the "odd" Walsh functions, analogous to the Fourier sine functions.

Sequency: Walsh function terminology referring to the Walsh components of a wave form in exactly the same way that frequency is used to refer to the Fourier components. Example: Sequency spectrum.

Spectrum: When orthonormal functions are used to analyze a wave form, the result frequently is a set of coefficients which weigh each of the basic functions found in a (theoretically) infinite sum which represents the wave form. Each coefficient corresponds to some parameter of the orthonormal functions, which might be, for example, a number "n." Whatever the parameter is, a spectrum for the analysis is obtained by plotting the coefficient values versus the parameter value for a large number of coefficients. For a Fourier analysis, the result is a plot of coefficient versus frequency (which at the low end corresponds to a small integer value). A Walsh spectrum would plot the coefficient of WAL (n) versus n.

Wave form: For the purposes of this article, a signal's wave form is a value of (for example) voltage as a function of time.■

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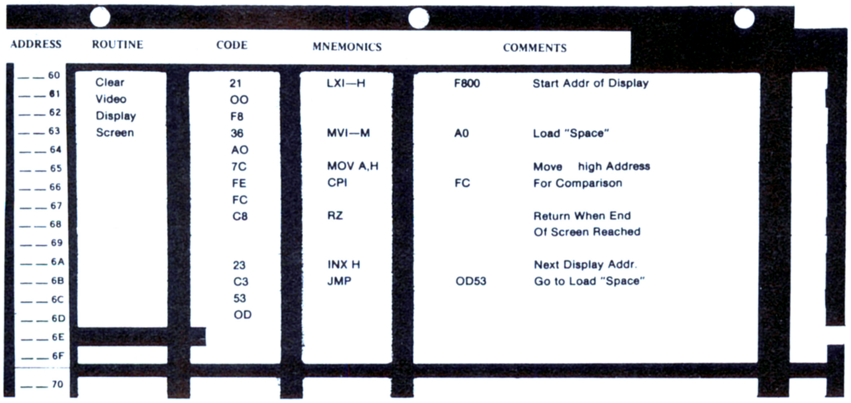

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— — 64		AO		
— — 65		7C	MOV A,H	Move high Address
— — 66		FE	CPI	FC For Comparison
— — 67		FC		
— — 68		C8	RZ	Return When End Of Screen Reached
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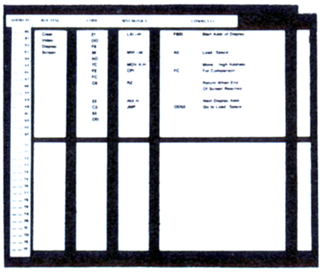

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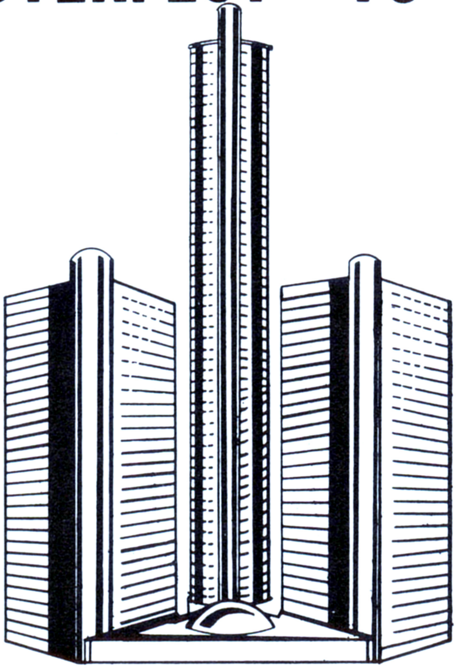

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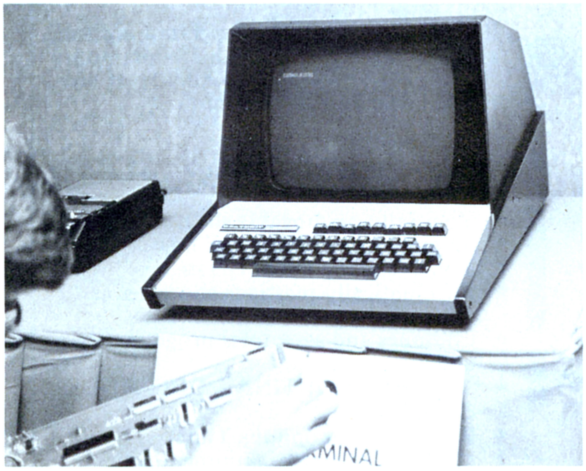

Photo 1: Perhaps a key element of the Heath line is this H9 video terminal, used with either the H8 or H11 systems. It is a full ASCII terminal (but with upper case only in the display section) and a wide range of data rates.

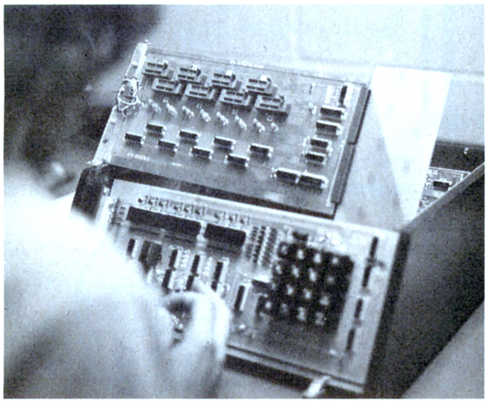

Photo 3: Here is an H8 computer used in a production and test situation at the Heathkit plant, with its memory board mounted on an extender. The boards in the H8 are mounted at an angle with respect to vertical, which keeps the height of the cabinet down while allowing bigger boards to be designed.

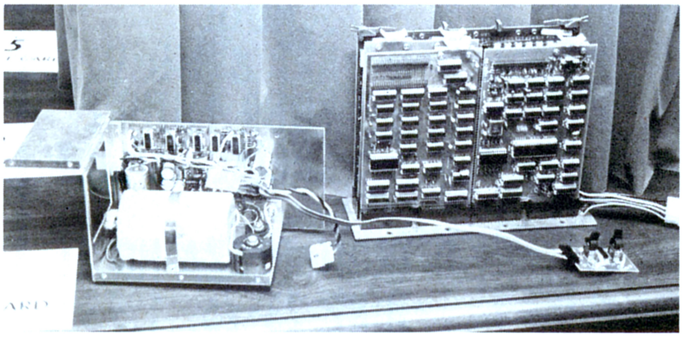

Photo 4: The "guts" of the H11 product by Heathkit are represented by the two boards shown here on the table in the press room. The DEC LSI-11 board and several peripheral and memory cards are mounted in the back plane assembly at right, and the switching regulated power supply for the system is shown at the left.

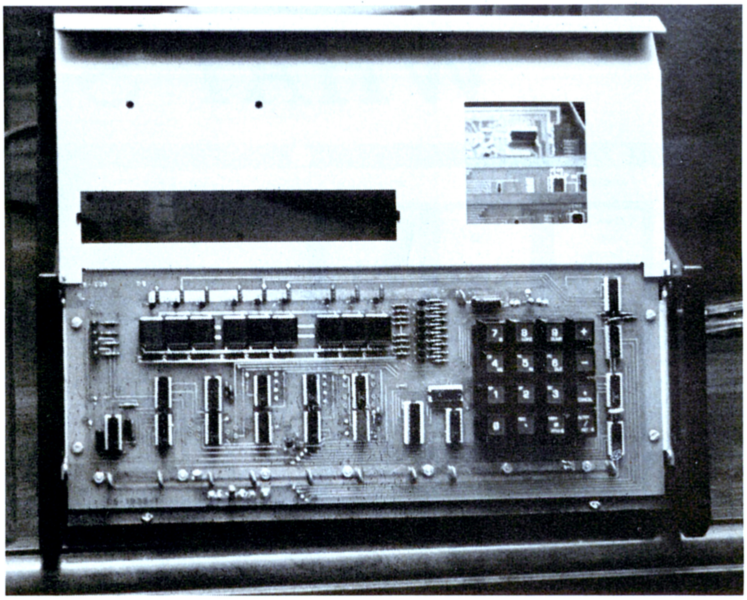

Photo 2: Flipping up the front panel of the demonstrator of the Heathkit H8 computer (an 8080 based product) in the press room revealed this lower level structure.

Some Candid Photos Shot in Benton Harbor

As noted in August 1977 BYTE, the Heathkit product line was introduced to the press June 1, to prime the publicity pumps in time for the August introduction of the line in public at the Personal Computing 77 show in Atlantic City. Here are some candid photos taken in the Heath plant in Benton Harbor MI during the press party.■

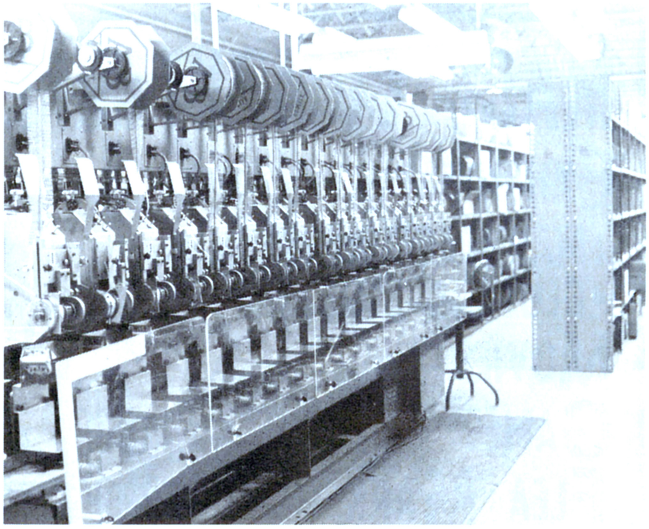

Photo 5: One point which many might overlook, but technology freaks can't ignore, is the specialized equipment which gets built when a firm has a large manufacturing operation. Here is a prime example of several very interesting cases of manufacturing automation at Heath: a machine which collates resistors prior to packing. Each reel holds a supply of resistors mounted on tape strips which many readers may have seen occasionally in surplus houses. The reel feeds a mechanism which removes the resistors from the tape on command and drops the resistor into a bin on a conveyor belt moving horizontally in a loop around the machine. The net result is that the human bag packers (not seen in this photograph) simply dump the properly collated resistor assortment from a bin into a bag and seal it, and have no need to physically handle each resistor. Such automation is possible only due to the uniformity of the resistors, and even then a machine tender is required to monitor occasional exception conditions.

NYU Conference

A conference on Computing in the Arts and Humanities will be held from Friday evening to Sunday noon, October 21 to 23 1977, at Warren Weaver Hall, New York University. Sponsored by ACM/SIGLASH (Association for Computing Machinery/Special Interest Group on Language Analysis and Studies in the Humanities) and the NYU Departments of Computer Science, Linguistics, Art and Art Education, Music and Music Education, the program will include:

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Friday evening: computing in the visual arts and presentations of video and film works.

Saturday evening: concert of music composed with the aid of computers.

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Grants will be made for surveys of: the US West of the Mississippi, the US East of the Mississippi, and Canada. Later grants will be made for surveys of other areas.

The reports will be published as part of the basic robotics literature, establishing their authors and supervisors as important contacts in the field.

Proposals from applicants are due on or before September 30 1977; completed reports are due on or before June 30 1978.

For details, write: Survey Grants, United States Robotics Society, Box 26484, Albuquerque NM 87125.■

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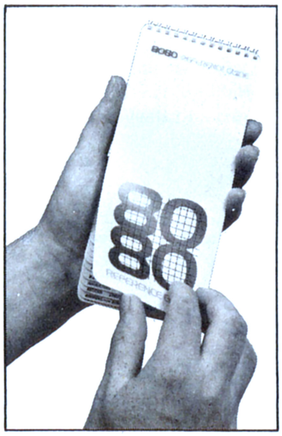

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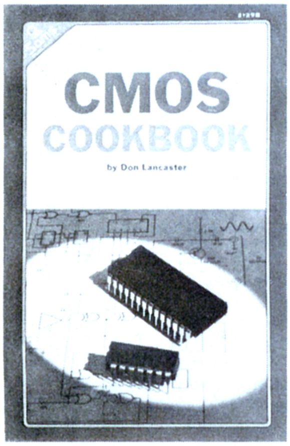
Book Reviews



CMOS Cookbook *by Don Lancaster, Howard W Sams and Company, Indianapolis IN, 1977. $9.95.*

This book will prove immensely useful to anyone interested in sophisticated logic design. Like the author's earlier *RTL* and *TTL Cookbooks,* it covers everything from basic principles and practical usage tips to relatively complete applications in a style that is informal, understandable, and very easy to read. If you want to learn about CMOS from the ground up, or if you want a handy reference source of CMOS circuit ideas, this book is for you.

The reader who is comfortable with TTL may doubt the book's claim that "CMOS is the first hassle-free digital logic family," but Don makes a good case. He cites its very low cost, low power requirements and wide power supply voltage ranges, open circuit inputs and wide output voltage swings, very high fanout, and tolerance of system noise. He doesn't neglect the disadvantages of CMOS, though, and warns about its sensitivity to input capacitance and its speed limitations. After reading this book, you will undoubtedly appreciate CMOS as a very practical alternative to TTL.

The following categories are among the subjects covered in the book:

- basic logic elements and transmission gates
- power supplies and the relationship between voltage, current and speed
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Besides covering basic gates and deMorgan's theorem, Don describes features unique to CMOS, such as transmission gate logic and his own "Mickey Mouse Logic" (M^2L). He goes on to discuss advanced logic design techniques using data selectors, read only memories (ROMs) and programmable logic arrays (PLAs). Finally Don gives some approaches to creative logic design, something for which he is famous. Although some of his suggestions, such as "use nonobvious codes or timing sequences," may make the reader shudder, this short section on design philosophy is very valuable.

Following the organization of his earlier books, the focus shifts to multivibrators. Basic astable and monostable multivibrators are covered, of course, but since he starts with more sophisticated CMOS packages, Don is able to present more interesting applications like data rate and touch-tone generators, equally tempered music and voltage controlled oscillators.

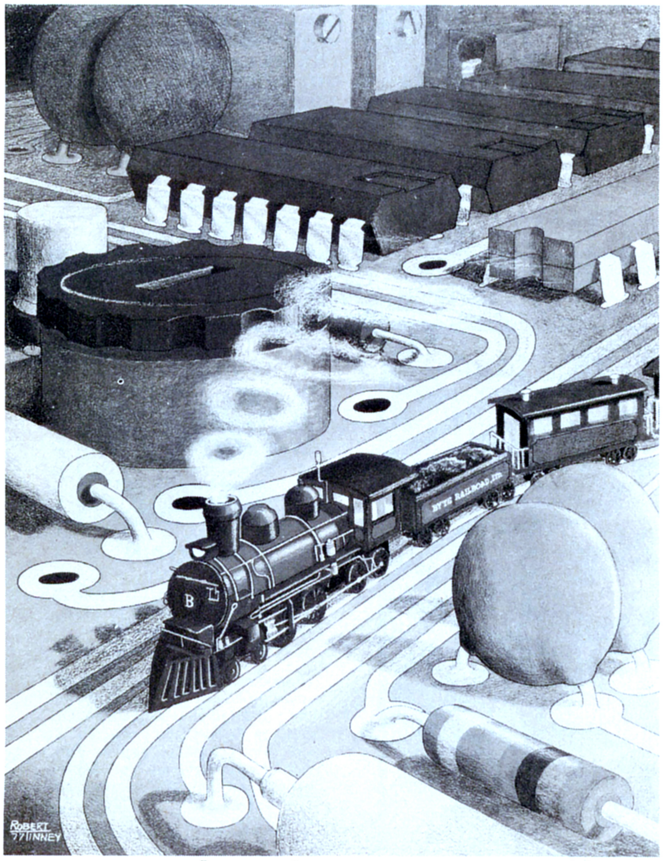
Succeeding chapters deal with clocked logic: flip flops, counters and shift registers. Although the basics are still covered, the more interesting examples exploit the special properties or the more sophisticated packages available with CMOS: touch and proximity sensors, phase detectors, character generator serial video and Teletype transmitters, and digital sine wave generators.

A very special chapter describes CMOS op amps, analog switches, and phase locked loops. The application examples for all three devices should give the reader a good grasp of their capabilities. The section on analog switches is especially interesting.

The final section of the book, "Getting It All Together," presents some larger scale designs, as well as challenges to the reader. Here you will find circuits for a video game, a digital wristwatch, and even a complete basic circuit and key waveforms for Don's TVT-4 television typewriter.

All in all, this book packs a lot of ideas into its 400 pages, and forms a superb introduction to an important new logic family. If you want to keep up-to-date on integrated circuit technology, you should not pass up this book.

Dan Fylstra
Hamilton Hall C-23
Harvard Business School
Boston MA 02163■



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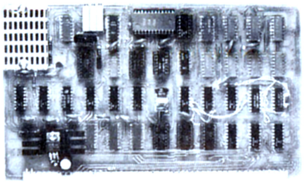

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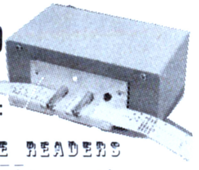

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Continued from page 21

Control Character	Meaning
Pnn	musical part number declaration, where nn=a number from 00 to 16
Knc	key signature declaration, where n is a number and c is a "+" or a "–"
Tn/n	time signature declaration; ie: "T4/4" means 4/4 time
Onn	positions the CDEFGAB scale on the terminal keyboard to octave nn of the external instrument's keyboard
( )nn	repeat text within parens nn times
< > = C	equate all text within brackets to symbol C
Q+n	transpose all subsequent text up n steps
Q–n	transpose all subsequent text down n steps
" "	all text within quotes is treated as commentary
CTRL A	marks the end of the MUSIC TEXT FILE

Table 2: Control characters used by the SCORTOS language processor.

matically informs the user when he has come to the end of a bar by displaying a slash and the next bar number on the terminal. This provides a checksum for each bar and a milestone to keep the operator informed of his position in the score. Listing 1 shows a sample of the dialog between the operator and the editor as the operator enters the score fragment in figure 3. The italicized type is supplied by the editor, the bold type by the operator.

Conventional string oriented text editors are inconvenient for use with music text since music is prone to have too many occurrences of any given string. Allowing the user to access the text by part number and bar number is more suitable since he refers to a written score in the same way. Various commands are available within the editor which allow a user to list selected bars and make insertions and deletions in the music text at selected bar boundaries.

The converter is the system's music language processor. It scans the text of the music text file and translates the logical entities of rhythm and pitch to the physical values of time and keyboard address. For each event described in the file the converter outputs a 2 byte record which contains the duration of that event in standard system timing units, and the location of the event on the system controlled music keyboards.

Table 2 is a list of control characters recognized by the converter. In keeping with the design goal of eliminating redundancies in the music score, an equate (=) statement was developed. Using equate, repeated groups of notes need only be typed in once and equated to a symbol. Thereafter they may be brought into the music source text by typing the symbol to which they have been equated.

The driver interface subroutines allow the user to communicate with the DRIVER by providing him access to the binary output file. Through their use, a sequence of musical events may be generated from within the computer by a user written program. For example, the researcher may have made an analysis of a particular composer's style (following the procedure described earlier in this article) and may wish to write a program in BASIC which creates a composition based upon the properties of that style. The sequence of events that constitute the composition would be produced by calls to the driver interface subroutines.

The EVENT subroutine is the principal interface subroutine. Its calling sequence is:

```
CALL EVENT
DS   ARG1
DS   ARG2
DS   ARG3
DS   ARG4
```

where:

ARG1 = part number.
ARG2 = duration of event.
ARG3 = address of keyboard switch.
ARG4 = slur code (0= no slur, 1= slur this event to next event).

The DRIVER is a software representation of the inner workings of a player piano where the binary output file, subroutine CLOCK, and the DRIVER's main code are the respective analogs of the piano roll, sprocket drive and mechanical read head. All of the control features of its mechanical counterpart are available within the program, including start performance, pause, and stop performance, and some which are unique to a software simulation, such as discrete tempo control and part selection.

The DRIVER causes music to be performed by initiating and terminating musical events according to the information contained in the binary output file. The program keeps a timer for each part that is participating in the performance. When an event is initiated, the address data in the event's data record is output to the appropriate 88-RCB data register. This causes sound to emanate from the instrument to which the 88-RCB is connected. The timer is set to zero, then incremented 20 times per second and compared at each incrementation to the event duration field of the event's data record. When these two quantities are equal, the event is terminated by a logical exclusive OR of that event's keyboard address data with the 88-RCB data register. The DRIVER then proceeds to the next event record and repeats the process.

Timing is provided internally by subroutine CLOCK which contains a timing loop and which also interprets control commands from the terminal. When a call is

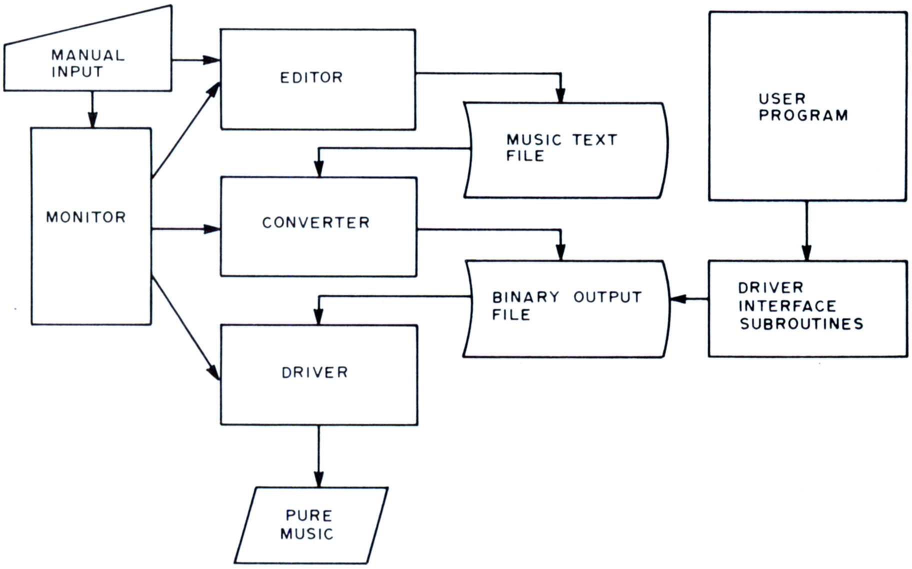

Figure 4: The flow of information through the SCORTOS software. The monitor controls the system's major functions. The editor allows the user to enter music through the computer's keyboard (see figure 1) and to modify it as desired. Listing 1 describes this in more detail. The converter scans the text of the music text file and converts the values for rhythm and pitch into physical values of time and keyboard address. The driver interface subroutines allow the computer to play music that it has composed based on stochastic or random elements contained in the user's programs.

made to CLOCK, the caller will not receive control back until a specified interval of time has passed. In this way it can be used as a time source. The time interval provided by CLOCK is used as the basic unit of time in the system. An interval of 1/20 of a second is sufficient to provide the resolution necessary to perform the most complex musical passages.

The internal generation of timing is less expensive and permits the tempo of the performance to be easily varied on line. By striking the keys labeled "rit" or "accel" on the terminal keyboard, the operator can retard or accelerate the tempo of the performance by 2.5% for each stroke of the key.

The use of processor cycles to generate timing puts a great strain on the DRIVER. It must complete its work so quickly that the listener is not aware of any delay between music parts that are supposed to be occurring simultaneously. Musicians can time a musical event to within 10 ms of its desired occurrence. This imposes on the DRIVER the specification that, for worst case condi-

Command	**Meaning**
*E ab	Call the EDITOR and load the source text file identified by the characters ab
*C ab,cd	Load the file identified by the two character code ab and use it as input to the CONVERTER. Write the output of the CONVERTER to file cd
*P cd	Load the file identified by the characters cd. Call the DRIVER and perform the music described by the data in file cd

Table 3: A list of command verbs recognized by the system monitor. Each verb calls a system module, and its arguments specify the data file which is to be operated on by that module.

```
EDITOR
COMMAND?          N
FILE CODE?        S5
ENTER PART NO.          P01
     0001       "SYMPHONY NO 5 (PROKOFIEV)*****OBOE" K2- T3/4 (2.)O3
     0005       P02
     0001       " 1st FLUTE " K2-T3/4 O3 F4 G4 A8. F16 /
     0002       O4 C8. O3 B16 O4 F4 B4 /
     0003       D8. E16 F4. G8 /
     0004       F8 E8 D8 C8 O3 B8 O2 C8 /
     0005       P03
     0001       " 2ND FLUTE " K2- T3/4 . . . . . . etc.
```

Listing 1: A sample of the dialog between the operator and the system editor as the operator enters the score fragment in figure 3. The italicized type is supplied by the editor.

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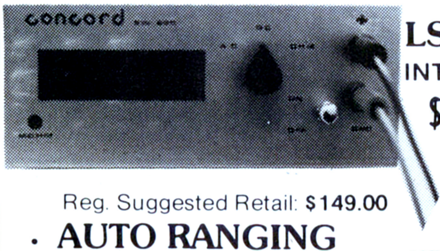

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tions, it must initiate an event for all 16 parts within the same period of time. For this reason great care was taken in the design of the program to ensure that its execution time is held to the minimum.

Conclusion

The functional possibilities addressed by the SCORTOS system are, of course rudimentary. In its present state it provides a foundation on which additional application programs can be built, notably a music language which treats the performer of the music as a computer and not a human. Other possibilities include a set-complex processor to analyze music and statistically model its characteristics, and a plotter interface that will draw musical scores on a plotter. Some of these programs already exist and need only be converted from FORTRAN to BASIC.

I am presently developing a macro capability that allows the user to equate a rhythm sequence to a symbol, and then associate different pitches with each note in the rhythm sequence by means of an argument list in a macro declaration.

The implications of this macro capability go further than just providing a way to eliminate redundancy. The composer often deals in "primitives" which are at a higher level than those allowed by his conventional music language. That is, the composer often thinks in terms of whole musical phrases and note groupings rather than individual notes of which he is compelled to construct those phrases and groupings. In using this higher level language, the composer is able to construct his compositions of larger building blocks and may easily vary the tonal parameters within those building blocks to achieve various aesthetic effects.

The purpose of the SCORTOS system project is to foster computer implemented composition among individuals and institutions whose financial and talent resources have prevented them from undertaking such projects in the past. Over the years various projects of this nature have been conducted at the larger educational centers of the country. The adoption of these projects by individuals and poorer institutions has not been widespread due to the large hardware costs involved, or lack of programming experience within the music departments. I hope that more modestly endowed music institutions will respond to a turnkey installation costing less than $10,000, and that we may shortly see the computer joining the synthesizer and tape recorder as standard equipment in every electronic music studio.■

Continued from page 98

What is the equivalent of the LIN(x) command, the GO TO . . . OF . . . command, the PRINT USING, and the IMAGE statements used in the program as listed? Also, when the program is compiled in VM 370 BASIC, lines 1520, 1600, 3370 and 3600 give the error message "NO. OF DIMENS. INVALID"; line 140 gives a "SYNTAX ERROR IN EXPRESSION: message. Can you suggest revisions to eliminate the problems and tell me where to get hold of a VM 370 BASIC manual?

Glenn Bultmann
2218 E Gatehouse Dr
Metairie LA 70001

LIN(x) is a built-in function in the BASIC version used by David Price, a function which is used for formatting control on the terminal. Its semantics are most likely: "advance the terminal by x lines."

PRINT USING and IMAGE are related statements, used to establish a format for output similar to the FORTRAN "FORMAT" statement in the version of BASIC used in David Price's article. The manual for VM 370 would have to be consulted to find the equivalent, or you could dispense with formats entirely (and get a much cruder output) by using PRINT instead of PRINT USING as a temporary measure.

The GO TO . . . OF . . . is the logical equivalent of a computed GO TO in FORTRAN, and probably exists also in the VM 370 BASIC. If you must implement it yourself, the semantics should be satisfied by a series of "IF" statements, as in the following conversion of line 780 of listing 1 of David Price's article, page 107 of the March 1977 BYTE:

New Line 720 code . . .

```
IF A+1 = 1 THEN GO TO 890
IF A+1 = 2 THEN GO TO 1520
IF A+1 = 3 THEN GO TO 1640
IF A+1 = 4 THEN GO TO 1800
IF A+1 = 5 THEN GO TO 2200
IF A+1 = 6 THEN GO TO 3010
IF A+1 = 7 THEN GO TO 3550
```

Of course, this example could be made more efficient by calculating the expression A+1 first and assigning its value to a variable; to avoid picking another variable name, we show this version of the logic.

The problems with lines 1520, 1600, 3370 and 3600 are due to the fact that the program as written by David Price uses a "substring" feature of the BASIC version he has access to. The notation A$(x,y) is (from the context of the version of the program we printed) a reference to the characters in string A$ starting at location x and extending to location y. Thus if A$ = "ANYTHING" then A$(3,5) has the value "YTH" by this interpretation. No simple conversion is possible; however, you can often achieve the same effect by using a FOR . . . NEXT loop scanning the required range of characters within the string and referencing the characters one at a time using A$(I) as a form which is most likely allowed in the VM 370 version of BASIC. (Check the manual on this, and possibly use an alternate substring notation if it exists). As for line 140, figuring out why it gives a syntax error would require reference to the manual; however, noting that many times exponentiation is indicated by a double asterisk (**) one likely place to start would be by replacing the up arrow exponentiation symbol by a double asterisk. (This symbol is the upward pointing caret (^) seen in line 140 as printed in March 1977 BYTE).

As for getting hold of the manual for VM 370 BASIC, the most likely place to start is a trip to the computing center which supports your terminal. Most computing centers for timesharing networks have some form of user accessible documentation library. Alternately use the formal channels at your center to order a manual from IBM, or contact IBM yourself. The company is usually only too happy to satisfy such requests for documentation, and the charges are nominal.■

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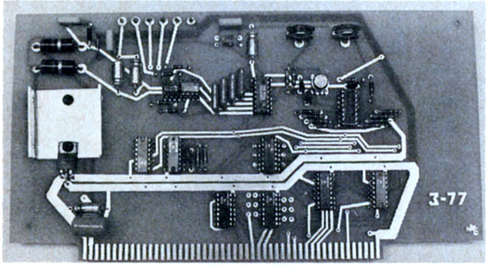

Pinnacle Products has announced a self-refreshing 4 channel digital to analog converter that is Altair bus compatible. Instructions are included for alternate connection to Digital Group Systems. Features include complete output port address decoding and a 3 state bus connection. The converter has eight bits of resolution and can be set to cover any range within −10 to 10 V. It operates at a rate of 50,000 conversions a second, updating the four sample and hold outputs from a scratch pad register. Circuit operation as seen from the computer is completely static; no software refresh or wait states are required. A 4 byte computer program is used to set up the unit.

The printed circuit board alone sells for $34. The complete kit is $69, and the assembled and tested board is $99. Contact Pinnacle Products, POB 3155, Talcottville CT 06066.■

Circle 646 on inquiry card.

The Noval 760 Operating Manual

Noval Inc, 8401 Aero Dr, San Diego CA 92123, (714) 277-8700, has completed the first edition of the *Noval 760 Operating Computer Operating Manual.* This 1 inch (2.5 cm) thick loose-leaf manual is available by itself for $20. The manual describes hardware characteristics of available modules, as well as the software of the firm's interactive assembly and editing system, BASIC interpreter, and utility routines.

This computer was developed by Gremlin Industries for in-house use as a design system for video arcade game and educational software, and should make an excellent option for many readers interested in graphics and complete systems with "turn key" characteristics. Use the manual alone if you want to investigate what this system package contains.■

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Sized at 11 by 14 inches (27.9 by 35.6 cm), the *Byte Shopper* catalog is hard to miss. Published by the Byte Shop of Arizona, 813 N Scottsdale Rd, Tempe AZ 85281, the new catalog describes a variety of microcomputers, video terminals, floppy disks and other personal computing items. A unique feature of the catalog is the tutorial information about personal computers, including a glossary of terms and short articles like: "What Can a Computer System Do?", "The Magic Bus" and "What Makes a Computer Smart?". The catalog is free for the asking.■

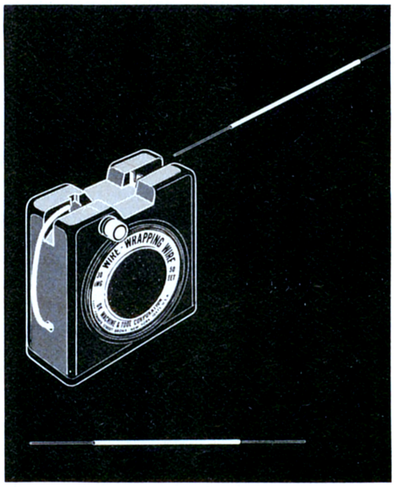
Circle 645 on inquiry card.

A Timely Kit for HP-45 Owners

Egbert Electronics, 1514 S 320 East, Orem UT 84057, has announced a new kit to improve the accuracy of the stopwatch function on the HP-45 calculator. As most owners of the unit know by now, the HP-45 can be turned into a stopwatch by first pressing RCL, and then simultaneously pressing CHS, 7 and 8. The kit provides a quartz crystal to stabilize the internal oscillator, plus associated electronics. Kit price is $13. Egbert Electronics will do the installation for $23.■

Circle 653 on inquiry card.

A New Wire Dispenser-Stripper for Wire Wrap and Other Applications



A new wire dispenser from OK Machine and Tool Company, 3455 Conner St, Bronx NY 10475, combines cutting and stripping ability in one unit. Wire is drawn out of the dispenser to the desired length, cut with the built-in plunger, and pulled through the stripping blades. Dispenser includes 50 feet (15 meters) of AWG 30 insulated solid copper wire available in four colors. People who use conventional wire wrap will find this to be an excellent addition to the tool kit. ■

Circle 648 on inquiry card.

Data General Enters the Personal Computing Market

The Computer Store, a chain of retail personal computer outlets in the Northeast, has announced that they will be distributing the entire line of Data General's Micro-NOVA microcomputers, peripherals and software.

Free catalogs are now available from The Computer Store, 120 Cambridge St, Burlington MA 01803, which describe the full line of products, including expansion memories and interfaces; DOS, RTOS, BASIC, FORTRAN and development software; the DASHER matrix printer and the 6000 line of video terminals.■

Circle 649 on inquiry card.

Digital Equipment's Comments on the Heathkit H11

The following information was received from Digital Equipment Corporation, one party to the synergistic twosome of Heath Company and DEC.

Digital Equipment Corporation announced the signing of a multimillion dollar contract for LSI-11 microcomputers and related products by Heath Company, a subsidiary of Schlumberger, Ltd. The microcomputers, to be delivered over a 3 year period, will be incorporated into Heath's H11 computer

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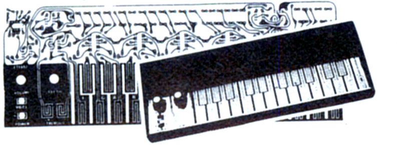

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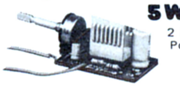

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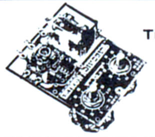

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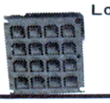

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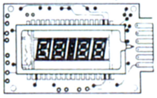

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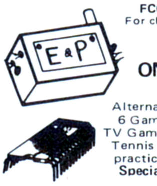

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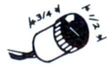

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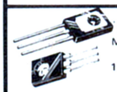

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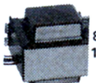

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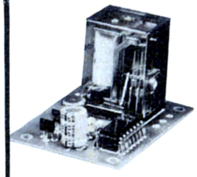

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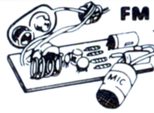

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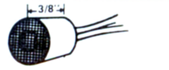

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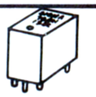

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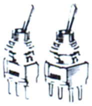

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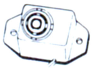

Mini Size 1"x3/4"x3/4"
Supply voltage 1.5V–12V
Ideal for Alarm or Tone Indicator
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Circle 303 on inquiry card.

kits, which will be marketed primarily for hobby, personal and small business applications via Heath's 50 stores and mail order catalog. The contract includes a licensing arrangement providing use of assembly and higher level programming languages such as PAL-11, ED-11, FOCAL and BASIC with the H11 computer.

Digital's microcomputer forms the central element of each H11 computer. Each is a full computer on a board with the operating characteristics of a standard PDP-11 16 bit minicomputer. Currently there are over 10,000 LSI-11s in use in a variety of applications ranging from scoreboard animation to complex medical instrumentation.

The H11 represents the top of Heath's line of computer kits. It is priced at $1,295 and is scheduled for shipment this fall.

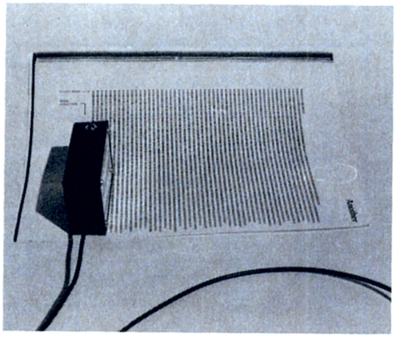
The LSI-11, unlike most other microcomputers, has a central processor with a full 16 bit word length. It comes with built-in memory of 4,096 word (8,192 byte) capacity. Console operations are microcoded so a terminal can be used for program control and debugging.

The instruction set of the LSI-11 is virtually identical to that of other PDP-11 computers, such as the PDP-11/34. Thus, sophisticated program development is achievable with the Heath H11.

Purchasers of the H11 will be eligible to join DECUS (the Digital Equipment Computer Users Society). DECUS functions as a clearing house for more than 28,000 members worldwide who wish to exchange programs and information. "DECUS holds special symposia and publishes a journal. The DECUS library contains over 800 programs designed for the PDP-11 family of computers, many of which were developed for or can run on the LSI-11," he said.

Circle 654 on inquiry card.

A New Bar Code Reader



Here is one answer to the question, "Where can I buy a bar code reader to read the bar code listings published in BYTE?". Jeffersonville Engineering Co, 605 E 10th St, Jeffersonville IN 47130, phone (812) 288-8246, has announced its new bar code reader. Priced at $39.95, the unit outputs +5 V on a bar and 0 V on a space; timing and translation are software dependent. 6502 and 8080 software is said to be currently available for use with the unit.

The company can also print bar code versions of customers' software. Contact them for further details.■

Circle 655 on inquiry card.

A New Chip on the Block

We received an interesting preliminary product description for a television raster scan display controller recently, sent in by a gentleman at SMC Microsystems Corporation, 35 Marcus Blvd, Hauppauge NY 11787. The product involved is a 40 pin N-channel MOS LSI device called the CRT 5027 Video Timer-Controller.

This device will be of some interest to those homebrewers and designers who are interested in a minimum hassle path to a raster scan display (where minimum is relative to homebrewing the same logic out of SSI and MSI parts).

What this device does is establish all frame formatting, character scanning and sync timing for a video display (with the single exception of the dot address counter which cannot be practically implemented in MOS integrated circuits). The video display functions use seven 8 bit control registers connected to a bi-directional byte oriented data bus with appropriate select lines allowing easy integration in the typical microprocessor system. The boxes entitled "Operation" and "Additional Features" accompanying this note are copied from page 3 of the SMC document, and summarize the salient features of the product.

Persons interested in seriously pursuing homebrew (or commercial) designs with this device are advised to write SMC for a copy of the brochure. Who will be the first reader to homebrew a high resolution graphic display using this chip for timing, about 16 K bytes of memory, and a good black and white monitor? Find out when (sooner or later) the task is accomplished and a construction project is documented as an article.■

Circle 631 on inquiry card.

Operation

The design philosophy employed was to allow the device to interface effectively with either a microprocessor based or hardwire logic system. The device is programmed by the user in one of two ways; via the processor data bus as part of the system initialization routine, or during power up via a PROM tied on the data bus and addressed directly by the Row Select outputs of the chip. (See figure 4). Seven 8 bit words are required to fully program the chip. Bit assignments for these words are shown in Table 1. The information contained in these seven words consists of the following:

Horizontal Formatting:	
Characters/Data Row	A 3 bit code providing 8 mask programmable character lengths from 20 to 132. The standard device will be masked for the following character lengths; 20, 32, 40, 64, 72, 80, 96, and 132.
Horizontal Sync Delay	3 bits assigned providing up to 8 character times for generation of "front porch".
Horizontal Sync Width	4 bits assigned providing up to 16 character times for generation of horizontal sync width.
Horizontal Line Count	8 bits assigned providing up to 256 character times for total horizontal formatting.
Skew Bits	A 2 bit code providing from a 0 to 2 character skew between the horizontal address counter and the horizontal blank and sync signals to allow for retiming of video data prior to generation of composite video signal. The Cursor Video signal is also skewed as a function of this code.
Vertical Formatting:	
Interlaced/Non-interlaced	This bit provides for data presentation with odd/even field formatting for interlaced systems. It modifies the vertical timing counters as described below.
Scans/Frame	8 bits assigned, defined according to the following equations: Let X = value of 8 assigned bits. 1) in interlaced mode—scans/frame = 2X + 513. Therefore for 525 scans, program X = 6 (00000110). Vertical sync will occur precisely every 262.5 scans, thereby producing two interlaced fields. Range = 513 to 1023 scans/frame, odd counts only. 2) in non-interlaced mode—scans/frame = 2X + 256. Therefore for 262 scans, program X = 3 (00000011). Range = 256 to 766 scans/frame, even counts only. In either mode, vertical sync width is fixed at three horizontal scans (≡ 3H).
Vertical Data Start	8 bits assigned providing scan line resolution in vertical data positioning with respect to vertical sync. The Data Row Counter is reset at vertical sync and will not begin counting until the scan line selected by these eight bits.
Data Rows/Frame	6 bits assigned providing up to 64 data rows per frame.
Last Data Row	6 bits to allow up or down scrolling via a preload defining the count of the last displayed data row.
Scans/Data Row	4 bits assigned providing up to 16 scan lines per data row.

Additional Features

Device Initialization:

Under microprocessor control—The device can be reset under system or program control by presenting a 0101 address on A0-3. The device will remain reset at the top of the even field page until a start command is executed by presenting a 0111 address on A0-3.

Via "Self Loading"—In a non-processor environment, the self loading sequence is effected by presenting and holding the 1111 address on A0-3, and is initiated by the receipt of the strobe pulse ($\overline{DS}$). The 1111 address should be maintained long enough to insure that all seven registers have been loaded (in most applications under one millisecond). The timing sequence will begin one line scan after the 1111 address is removed. In processor based systems, self loading is initiated by presenting the 1110 address to the device. Self loading is terminated by presenting the start command to the device which also initiates the timing chain.

Scrolling—In addition to the Register 6 storage of the last displayed data row a "scroll" command (address 1101) presented to the device will increment the first displayed data row count to facilitate up scrolling in certain applications.

TERMS: Prices good through 9/30/77. Orders under $10 add 50¢. Please include up to 5% for shipping; excess refunded (may be more with item like power supply). Californians add tax. CODs accepted with street address.

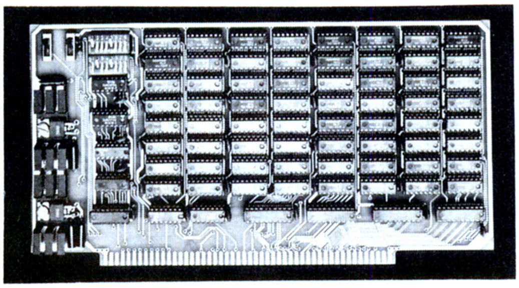
the GODBOUT GAZETTE

Bill Godbout Electronics
PO Box 2355 Oakland CA 94614

CREDIT CARD ORDERS / 24 HOUR ORDER DESK: Place BankAmericard®/Mastercharge® /Visa® charge card orders ($15 minimum) by calling **(415) 562-0636**, 24 hours. By the way, do you have our flyer? You probably should.

GODBOUT'S INTRODUCES 24K OF MEMORY FOR $450 ; HOBBYISTS REJOICE !

INCLUDES STATIC DESIGN, TRI-STATE OUTPUTS, S100 BUSS COMPATIBILITY



EXCLUSIVE TO THE GAZETTE

It is now possible to purchase three 8K Econoram II™ boards for $450. A single 8K board, the fastest selling computer kit in Godbout's history, is still available for $163.84.

"We wanted to make it possible for the computer hobbyists to stuff a lot of memory into their machines at a reasonable price", Bill Godbout is quoted as saying today. Judging from the response, he seems to have succeeded.

However, a representative for the company stressed that price was not the only attractive feature of this board, citing the low current consumption (1.5A guaranteed, 1250 mA typical) and high speed (0 wait states). For users of Z-80 processors driven by a 4 Mhz clock, there is even on-board logic for implementing 1 wait state.

He added, "the vector interrupt feature, which lets you know if you are trying to write into protected memory, is very handy. Also, the board was designed to be configured as two, separately addressable 4K blocks which adds considerably to the versatility."

A poll of users, undertaken by Godbout's, shows that hobbyists are pleased by the all-static design, which eliminates dynamic timing problems. Others find the tri-state outputs, and fully buffered inputs and outputs, to be their favorite features. All agree that the quality is exceptional, from the legended and solder masked board to the low profile sockets.

Those wishing to take advantage of the special 3/$450 offer should ask for #SPC-24. The standard 8K board ($163.84) is stock number CK-008; an assembled version, #CK-010, is available for $188.50. A 4K version of the board costs $100 in kit form (#CK-007) and $120 assembled (#CK-009).

PARTS FORECAST

A cooling trend is forecast, with the warm TTL front being weakened by cooler, lower power ICs such as CMOS and low power Schottky. As this colder front moves in, we can expect lower prices and decreased emphasis on husky power supplies.

CMOS

4000	$0.25	4037	0.50
4001	0.29	4040	1.50
4002	0.34	4041	0.85
4007	0.29	4042	0.85
4008	1.28	4043	0.60
4009	0.53	4044	0.60
4010	0.53	4047	1.63
4011	0.29	4049	0.50
4012	0.29	4050	0.50
4013	0.50	4051	1.03
4014	1.23	4052	1.03
4015	0.90	4053	1.03
4016	0.45	4060	1.48
4017	1.23	4066	0.58
4019	0.55	4069B/	
4020	1.50	74C04	0.33
4021	1.23	4070	0.60
4022	1.20	4071	0.33
4023	0.29	4073	0.33
4024	1.03	4075	0.33
4025	0.29	4076B/	
4027	0.75	74C173	1.63
4028	1.00	4081	0.33
4029	1.73	4116	0.50
4030	0.53	14511	2.00
4033	1.50		

Low Power SCHOTTKY

74LS00	$0.30	74LS151	0.95
74LS01	0.30	74LS155	1.38
74LS02	0.30	74LS157	0.95
74LS04	0.33	74LS160	1.40
74LS08	0.36	74LS161	1.40
74LS10	0.30	74LS162	1.40
74LS11	0.36	74LS163	1.40
74LS12	0.33	74LS168	1.87
74LS14	1.38	74LS169	1.87
74LS15	0.30	74LS173	1.65
74LS20	0.30	74LS174	1.25
74LS21	0.33	74LS175	1.15
74LS22	0.33	74LS195	1.30
74LS26	0.43	74LS240	1.88
74LS27	0.36	74LS257	1.25
74LS30	0.30	74LS258	1.25
74LS32	0.38	74LS266	0.53
74LS37	0.45	74LS283	1.20
74LS38	0.45	74LS365/	
74LS42	0.98	80LS95	0.75
74LS47	1.00	74LS366/	
74LS48	0.98	80LS96	0.75
74LS74	0.50	74LS367/	
74LS75	0.68	80LS97	0.75
74LS76	0.50	74LS368/	
74LS86	0.50	80LS98	0.75
74LS109	0.50	74LS386	0.55
74LS125	0.63	81LS95	1.13
74LS126	0.63	81LS96	1.13
74LS132	1.25	81LS97	1.13
74LS138	1.10	81LS98	1.13
74LS139	1.15		

Energy Crisis Hits Home

Computer owners from coast to coast have complained of a lack of available energy for their computers. The problem lies not with power generating stations, but rather with the shortage of compact, low priced power supplies capable of providing the many voltages required by microprocessing systems. Experimenters also report being frustrated by the lack of power supplies.

However, the Gazette has confirmed existence of a solution to this energy crisis. Our highly placed source, nicknamed "deep volt", has leaked the following information about a "CPU Power Supply", also known by its stock number (#CK-014).

"The unit appears to be a well thought out supply, which delivers 5V @ 4A with crowbar overvoltage protection, along with ½ Amp of +12V and ½ Amp of -12V. A particularly sneaky feature is an adjustable 10 mA bias supply, required by some CPUs, that is often not included in other units. **Those who say there are no economical power supplies for small systems are in for a shock as the price is a mere $50.**

"Despite rumors of a power supply energy crisis, with wildly inflated prices forced on a public with no other choice, it seems that the Godbout CPU Power Supply should lay these misconceptions to rest permanently."

MOTHERS SAFE FROM BUSS POLLUTION

Many motherboards have reported flu-like symptoms (coughing, sneezing, dropping bits, scrambling data) when loaded with more than a few peripheral boards. It seemed that these motherboards lacked antibodies capable of rejecting noise, crosstalk, overshoot, etc. This is commonly called "buss pollution".

However, it was discovered that a particular group of motherboards, located in the wilds of the Oakland Airport, had developed an immunity to buss pollution.

It seemed these motherboards had active termination circuitry, and that's what accounted for the difference. Old motherboards may be immunized by simply plugging in an **Active Terminator Network** (#CK-017, **$29.50**).

Or, if you want a new motherboard, Godbout's has two --- both with active terminations, lots of bypass caps, and heavy PC board traces:

#CK-015, a **10/11 Slot Motherboard**, comes with 10 edge connectors and is excellent for adding on to small systems. **$90.00**

#CK-016, an **18 Slot Motherboard**, includes 18 edge connectors and is ideal for starting a stand-alone system. **$124.00**

Processor Prices Plummet

The workhorse 8080A, darling of the chip set, has reached a new low in pricing. Prime, new full spec units cost only **$12.95** regardless of quantity purchased when you order part #SPC-22.

In a parallel development memory prices continue to drop. Full speed 2708s are now available for **$25.00**; order part #SPC-23.

COMPUTER STRIKE AVERTED

Things looked tough at the negotiating tables located at computer stores throughout the country. The heart of the problem was a common computer grievance: having to shuttle programs in and out of their RAMs, thus hampering their productivity, and tying up work for hours at a time. Computers also complained of abuse at the hands of owners, who became enraged when programs went down the drain if the power went off for even a split second.

When the Godbout team of negotiators arrived on the scene, the computers showed a new spirit of compromise. After all, many of them had Godbout memories inside their cases---and computers are known for their loyalty.

The solution: the computers would go on working, if the owners plugged Godbout Econorom II™ boards into their systems. Then, they would't have to worry about losing their minds if the power went away, because Econoroms hold programs and routines in eraseable read only memory. So that owners wouldn't face undue hardship due to the extra expense Godbout's introduced several different boards, of various price levels and complexities. All of them feature 1K of static RAM as part of the memory; all of them are compatible with the S-100 buss used by Altair, IMSAI, and many others. They can be programmed by the Godbout Programming Service, or may be shipped unprogrammed.

Many computers, however, specifically suggested the 8080 software board. This 4K Econorom II is programmed with editor and assembler routines for the 8080, very much like the old Econorom; but this newer version has improved listings, which are a natural for getting any 8080 system up and running. For the benefit of any computers who did not receive word of the strike settlement, listed below are the boards offered by Godbout's:

#**CK-002** (Smaller) Econorom II™; 2K X 8 of EROM............**$195.00**

#**CK-003** (Basic) Econorom II™; 4K X 8....................**$250.00**

#**CK-004** (Bigger) Econorom II™; 8K X 8, configured as two separate 4K blocks...........**$350.00**

#**CK-005** 8080 Software Board A valuable first step in breaking away from machine language programming..............**$265.00**

TANTALUMS PICKED TO CLICK

Tantalum capacitors, long a favorite of industrial contractors where price is no object, are famous for their low series resistance. Now, Godbout's is making them available to the electronics hobbyist at popular prices. The list below shows all tantalum capacitors known to be in existence at the Godbout warehouse.

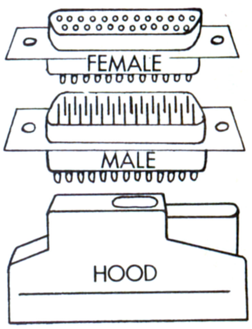
#CT0.47U	.47 uF 35V	4/$1.00
#CT2.2U	2.2 uF 20V	4/$1.00
#CT2.7U	2.7 uF 20V	4/$1.00
#CT3.3U	3.3 uf 15V	4/$1.00
#CT4.7U	4.7 uF 10V	4/$1.00
#CT22U	22 uF 10V	3/$1.00
#CT33U	33 uF 10V	3/$1.00
#CT39U	39 uF 10V	3/$1.00
#CT47U	47 uF 6V	3/$1.00

(advertisement)

I GOT IT AT
GODBOUT

T-SHIRT!
$5.00

Scientists discover missing link



Scientists have long puzzled over the "missing link" between computers and the outside world. Many have searched for this missing link, known in scientific circles as the DB-25 connector.

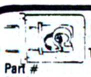
Extensive diggings at a certain manufacturer have resulted in the finding of this missing link by Godbout's trained researchers. They have isolated this missing link into three actual links, each of which performs a needed function in the crucial computer / outside world interface.

#CK-1004 - DB25P 25 pin RS-232 connector, sub mini D type, male plug with plastic hood. **$3.95**

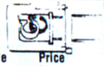
#CK-1005 - DB25S 25 pin RS-232 connector, sub mini D type, female jack. **$3.95**

#CK-1006 - DB25H plastic hood, which slips over the male plug to keep dust and glop from gumming up your connector. **$0.90**

Circle 304 on inquiry card.



CRYSTALS



THESE FREQUENCIES ONLY

Part #	Frequency	Case/Style	Price
CY1A	1.000 MHz	HC33/U	$5.95
CY2A	2.000 MHz	HC33/U	$5.95
CY2.01	2.010 MHz	HC33/U	$1.95
CY3A	4.000 MHz	HC18/U	$4.95
CY7A	5.000 MHz	HC18/U	$4.95
CY12A	10.000 MHz	HC18/U	$4.95
CY14A	14.31818 MHz	HC18U	$4.95
CY19A	18.000 MHz	HC18/U	$4.95
CY22A	20.000 MHz	HC18/U	$4.95
CY30B	32.000 MHz	HC18/U	$4.95

XR-2206KB Kit $29.95 Special **XR-2206KA Kit $19.95**

EXAR

WAVEFORM GENERATORS

XR-205	$8.40
XR-2206CP	4.49
XR-2207CP	3.85

STEREO DECODERS

XR-1310CP	$3.20
XR-1310EP	3.20
XR-1800P	3.20
XR-2567	2.99

MISCELLANEOUS

XR-2211CP	$6.70
XR-4136	.99
XR-1468	3.85
XR-1488	5.80
XR-1489	4.80
XR-2208	5.20

TIMERS

XR-555CP	$ .39
XR-320P	1.55
XR-556CP	1.85
XR-2556CP	3.20
XR-2240CP	3.25

PHASE LOCKED LOOPS

XR-210	5.20
XR-215	6.60
XR-567CP	1.95
XR-567CT	1.70

CONNECTORS

PRINTED CIRCUIT EDGE-CARD

.156 Spacing-Tin-Double Read-Out

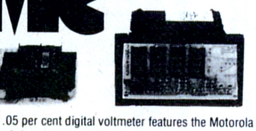
Bifurcated Contacts — Fits .054 to .070 P.C. Cards

15/30	PINS (Solder Eyelet)	$1.95
18/36	PINS (Solder Eyelet)	$2.49
22/44	PINS (Solder Eyelet)	$2.95
50/100	PINS (Wire Wrap)	$6.95
50/100A (.100 Spacing)	PINS (Wire Wrap)	$6.95

25 PIN-D SUBMINATURE

DB25P	PLUG	$3.25
DB25S	SOCKET	$4.95

IMC 3½ DIGIT DVM KIT



This 0-2 VDC .05 per cent digital voltmeter features the Motorola 3½ digit DVM chip set. It has a .4'' LED display and operates from a single +5V power supply. The unit is provided complete with an injection molded black plastic case complete with Bezel. An optional power supply is available which fits into the same case as the 0-2V DVM allowing 117 VAC operation.

A. 0-2V DVM with Case $49.95

B. 5V Power Supply $14.95

Etching Kits

32 X A-1	P.C. Etch Materials Kit enough for 5 circuit boards	$29.95 ea.
27 X A-1	Etched Circuit Kit Complete kit — only add water	$ 9.95 ea.

Plugboards

3662	6.5 X 4.5 X 1/16 Epoxy glass P-Pattern-44 P.C. Tabs-spaced .156''	$ 6.95 ea.
22/44	Mating connector for plugboard — 22 pin double readout	$ 2.95 ea.
8800V	Universal Microcomputer/Processor plugboard — Epoxy Glass — complete with heatsink and mounting hardware 5.313 X 10 X 1/16 copper clad	$19.95 ea.

Vector

1/16 VECTOR BOARD

	0.1'' Hole Spacing Part No.	P-Pattern L	P-Pattern W	Price 1	Price 2-Up
PHENOLIC	64P44 062XXXP	4.50	6.50	1.72	1.54
	169P44 02XXXP	4.50	17.00	3.69	3.32
EPOXY GLASS	64P44 062	4.50	6.50	2.07	1.86
	84P44 062	4.50	8.50	2.56	2.31
	169P44 062	4.50	17.00	5.04	4.53
	169P84 062	8.50	17.00	9.23	8.26
EPOXY GLASS COPPER CLAD	169P44 062C1	4.50	17.00	6.80	6.12

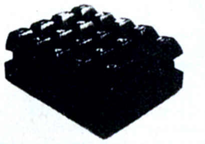
Vector

SLIT-N-WRAP WIRE WRAP TOOL

- Slits and opens insulation exposing bare wire
- No pre-cutting or pre-stripping.
- Comes complete with two - 100 ft spools #28 AWG wire

Model P180 $24.50

HEXADECIMAL ENCODER 19-KEY PAD



- 1 - 0
- ABCDEF
- Return Key
- Optional Key (Period)
- — Key

$10.95 each

63 KEY KEYBOARD

This keyboard features 63 unencoded SPST keys, unattached to any kind of P.C.B. A very solid molded plastic 13'' x 4'' base suits most applications.

$24.95

HD0165 16 LINE TO FOUR BIT PARALLEL KEYBOARD ENCODER $7.95

TOOLS

A97MS	— Diagonal Cutter - 4'' semi-flush cut	$8.50 ea.
A11DMS	— Chain Nose Pliers - 4¾'' long	7.50 ea.
T-6	— Wire Stripper - #16 to #26 gauge	3.75 ea.
55B	— Wire Stripper - #10 to #20 gauge	2.50 ea.
CS-8	— Cutter-Crimper Tool - 8¼'' long	8.50 ea.
Nippling Tool	— Cuts, Trims or Notches Metal up to #18 gauge	6.95 ea.
Nibbling Tool Replacement Punch		3.75 ea.

PERMACEL® P-29 PLUS Electrical Tape - All Weather

- ¾'' wide x 66 ft. • Black vinyl

1-9 Rolls **$.79 each** 10-up Rolls **$6.95/10 roll package**

MICROPROCESSOR COMPONENTS

8080A	CPU	$19.95
8212	8 Bit Input/Output	4.95
8214	Priority Interrupt Control	15.95
8216	Bi-Directional Bus Driver	6.95
8224	Clock Generator/Driver	10.95
CDP1802	- with user manual	39.95
8228	System Controller - Bus Driver	$10.95
MC6800L	8 Bit MPU	35.00
MC6820L	Periph. Interface Adapter	15.00
MC6810AP1	128 x 8 Static RAM	6.00
MC6830L8	1024 x 8 Bit ROM	18.00
Z80	CPU	49.95

CPU'S

8080	Super 8008	24.95
8080A	Super 8008	19.95
2650	8 BIT MPU	26.50

SR'S

2504	1024 Dynamic	$ 3.95
2518	Hex 32 BIT	7.00
2519	Hex 40 BIT	4.00
2524	512 Dynamic	2.49
2525	1024 Dynamic	6.00
2527	Dual 256 BIT	3.95
2529	Dual 512 BIT	4.00
2532	Quad 80 BIT	3.95
2533	1024 Static	Special 5.95
3341	Fifo	6.95
74LS670	16 x 4 Reg.	3.95

UART'S

AY-5-1013	30K Baud	$5.95

ROM'S

2513(2140)	Char. Gen.-upper case	$ 9.95
2513(3021)	Char. Gen.-lower case	9.95
2516	Char. Gen.	10.95

RAM'S

1101	256 x 1	Static	$ 1.49
2101	256 x 4	Static	5.95
2102	1024 x 1	Static	1.75
2107/5280	4096 x 1	Dynamic	4.95
2111	256 x 4	Static	6.95
7489	16 x 4	Static	2.49
8101	256 x 4	Static	6.95
8111	256 x 4	Static	6.95
8599	16 x 4	Static	3.49
91L02	1024 x 1	Static	2.25
74200	256 x 1	Static	6.95
93421	256 x 1	Static	2.95
MM5262	2K x 1	Dynamic	2 for 1.00

PROMS

1702A	2048	Famos	$ 9.95
5203	2048	Famos	14.95
82S23	32 x 8	Open C	5.00
82S123	32 x 8	Tristate	5.00
74S287	1024	Static	7.95
3601	256 x 4	Fast	3.95
2708	8K	Eprom	29.95
6301-1	1024	Tri-State Bipolar	3.49
6330-1	256	Open Collector Bipolar	2.95
6331-1	256	Tri-State Bipolar	2.95

SPECIAL REQUESTED ITEMS

FCM3817	$ 5.00						
AY-3-8500-1	$16.95					8T97	2.00
MC3061P	3.50	CD4508	6.75	82S115	25.00	3341	6.95
MC4016P (74416)	7.50	CD4515	6.50	5841	9.95	9368	3.95
MC14583	3.50	CD4520	2.70	MK50240	17.50	MC1408L7	9.95
MC14562	14.50	MCM6571	17.50	11C90	19.95	LD110/LD111	25.00/set
CD4059	9.95	MCM6574	17.50	DS0026CH	3.75	AY-5-9100	17.50 ea.
CD4070	.95	MCM6575	17.50	TIL308	10.50	95H90	13.95
MC14409	14.95	MC14419	14.95	ICM7208	22.00	ICM7209	7.50
MC14410	14.95	ICM7045	24.95	ICM7207	7.50	HD0165	7.95

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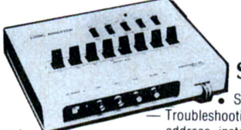
Logic Analyzer Kit



MODEL 100A $189.00/Kit

- Analyzes any type of digital system
- Checks data rates in excess of 8 million words per second
- Trouble shoot TTL, CMOS, DTL, RTL, Schottky and MOS families
- Displays 16 logic states up to 8 digits wide
- See ones and zeros displayed on your CRT, octal or hexadecimal format
- Tests circuits under actual operating conditions
- Easy to assemble — comes with step-by-step construction manual which includes 80 pages on logic analyzer operation.

- Some applications are:
  - — Troubleshooting microprocessor address, instruction, and data flow
  - — Examine contents of ROMS
  - — Tracing operation of control logic
  - — Checking counter and shift register operation
  - — Monitoring I/O sequences
  - — Verifying proper system operations during testing

TIRGGER EXPANDER — Model 10
Adds 16 additional Bits — Connects direct to Model 100A (Optional baseplate permits mounting to 100A for integrated unit) (Baseplate — $12.00) **Model 10 — $229.00**

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PB103 - 9'' x 6''	59.95
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20 MHz-100MHz — 8 digit — .6'' LED
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Logic Monitor $84.95
for DTL, HTL, TTL or CMOS Devices

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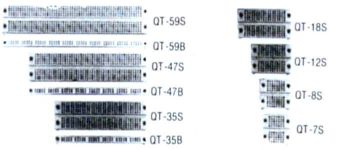

QT type	#holes	price
QT-59S	590	12.50
QT-59B	bus strip	2.50
QT-47S	470	10.00
QT-47B	bus strip	2.25
QT-35S	350	8.50
QT-35B	bus strip	2.00
QT-18S	180	4.75
QT-12S	120	3.75
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QT-7S	70	3.00

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- Doze Button
- 100% Solid State
- Large Red Led Display (.8'' high)
- AM/PM Indicator
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SEVEN DIFFERENT INSTRUMENTS!

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3 FUEL LEVEL
Percentage
Low Fuel Indicator

4 SPEEDOMETER*
0-99 MPH

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0-80 PSI

6 OIL TEMP
200-350° F

7 BATTERY MONITOR
±1 Volts From 11-15 VDC

BRIGHT YELLOW ORANGE
.3'' LED DISPLAY!

Kit includes case, bracket and all components — complete. Nothing else to buy! 12 Volt NEG GRD.

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- Bright 6 Digit LED Display
- Times to 59 minutes 59:59 seconds
- Crystal Controlled Time Base
- Three Stopwatches in One
  Times Single Event — Split & Taylor
- Size 4.5'' x 2.15'' x .90'' (4½ ounces)
- Uses 3 Penlite Cells.

Kit — $39.95
Assembled — $49.95
Heavy Duty Carry Case $5.95

Stop Watch Chip Only (7205) $19.95

QUARTZ DIGITAL AUTO CLOCK OR ELAPSED TIMER!

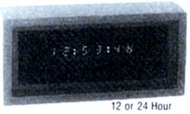
Elapsed Timer: Hrs, Mins and Secs
12 or 24 Hr Capacity
Simple Reset - Start Pushbutton Control

Complete kit includes mounting bracket, case and all components, nothing else to buy. Features MM5314 chip: Large .4'' LED's. Accuracy better than ± min. per mo. internal battery backup. 12 volt non-polar operation.

DIMENSIONS: 4½'' x 4'' x 2''
12 or 24 HOUR MODE

Kit: $29.95
Assembled: $39.95

CASE ONLY (includes hardware, mounting bracket and bezel) **$6.50**



12 or 24 Hour

115 VAC

JE700 CLOCK

The JE700 is a low cost digital clock, but is a very high quality unit. The unit features a simulated walnut case with dimensions of 6'' x 2½'' x 1''. It utilizes a MAN72 high brightness readout, and the MM5314 clock chip.

$17.95

DIGITAL CLOCK KIT — 3½ INCH DIGITS

4 DIGIT KIT $49.95 **4 DIGIT ASSEMBLED $59.95**
6 DIGIT KIT $69.95 **6 DIGIT ASSEMBLED $79.95**

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Specify 12 or 24 Hour When Ordering

JE803 PROBE

The Logic Probe is a unit which is for the most part indespensible in trouble shooting logic families TTL, DTL, RTL, CMOS. It derives the power it needs to operate directly off of the circuit under test, drawing a scant 10 mA max. It uses a MAN3 readout to indicate any of the following states by these symbols: (H) - 1 (LOW) - o (PULSE) - P. The Probe can detect high frequency pulses to 45 MHz. It can't be used at MOS levels or circuit damage will result.

$9.95 Per Kit

printed circuit board

T²L 5V 1A Supply

This is a standard TTL power supply using the well known LM309K regulator IC to provide a solid 1 AMP of current at 5 volts. We try to make things easy for you by providing everything you need in one package, including the hardware for only:

$9.95 Per Kit

Circle 305 on inquiry card.

7400N TTL

SN7400N	.16	SN7459A	.25		
SN7401N	.16	SN7460N	.22	SN74154N	1.00
SN7402N	.21	SN7470N	.45	SN74155N	.99
SN7403N	.16	SN7472N	.39	SN74156N	.99
SN7404N	.18	SN7473N	.37	SN74157N	.99
SN7405N	.24	SN7474N	.32	SN74160N	1.25
SN7406N	.20	SN7475N	.50	SN74161N	.99
SN7407N	.29	SN7476N	.32	SN74163N	.99
SN7408N	.25	SN7479N	5.00	SN74164N	1.10
SN7409N	.25	SN7480N	.50	SN74165N	1.10
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SN7411N	.30	SN7483N	.70	SN74167N	5.50
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SN7414N	.70	SN7488N	3.50	SN74173N	1.50
SN7416N	.35	SN7489N	2.49	SN74174N	1.25
SN7417N	.35	SN7490N	.45	SN74175N	.99
SN7420N	.21	SN7491N	.75	SN74176N	.90
SN7421N	.33	SN7492N	.49	SN74177N	.90
SN7422N	.49	SN7493N	.49	SN74180N	.99
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SN7425N	.29	SN7495N	.79	SN74182N	.95
SN7426N	.29	SN7496N	.89	SN74184N	1.95
SN7427N	.37	SN7497N	4.00	SN74185N	2.20
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SN7438N	.27	SN74123N	.50	SN74191N	1.25
SN7439N	.25	SN74125N	.60	SN74192N	.89
SN7440N	.15	SN74126N	.60	SN74193N	.89
SN7441N	.89	SN74132N	1.09	SN74194N	1.25
SN7442N	.59	SN74136N	.95	SN74195N	.75
SN7443N	.75	SN74141N	1.15	SN74196N	1.25
SN7444N	.75	SN74142N	4.00	SN74197N	.75
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SN7447N	.69	SN74145N	1.15	SN74200N	5.59
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CD4006	2.50	CD4040	2.45	74C30N	.65
CD4007	.25	CD4042	1.90	74C42N	2.15
CD4009	.59	CD4044	1.50	74C73N	1.50
CD4010	.59	CD4046	2.51	74C74	1.15
CD4011	.25	CD4047	2.75	74C90N	3.00
CD4012	.25	CD4049	.79	74C95N	2.00
CD4013	.47	CD4050	.79	74C107N	1.25
CD4016	.56	CD4051	2.95	74C151	2.90
CD4017	1.35	CD4053	2.95	74C154	4.00
CD4019	.55	CD4060	3.25	74C157	2.15
CD4020	1.49	CD4066	1.75	74C160	3.25
CD4022	1.25	CD4069	.45	74C161	3.25
CD4023	.25	CD4071	.45	74C163	3.00
CD4024	1.50	CD4081	.45	74C164	3.25
CD4025	.25	CD4511	2.50	74C173	2.60
CD4026	$3.95	CD4518	2.50	74C193	2.75
CD4027	.69	MC14566	3.00	74C195	2.75
CD4028	1.65	74C00N	.39	MC4044	4.50
CD4029	2.90	74C02N	.55	MC14016	.56

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LM301H	.35			LM1414N	1.75
LM301CN	.35	78MG	1.75	LM1458C	.65
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LM304H	1.00	LM373N	3.25	LM1556V	1.85
LM305H	.95	LM377N	4.00	LM2111N	1.95
LM307CN	.35	LM380N	1.39	LM2901N	2.95
LM308H	1.00	LM380CN	1.05	LM3065N	.69
LM308CN	1.00	LM381N	1.79	LM3900N	.55
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LM320K-5.2	1.35	NE560B	5.00	75451CN	.39
LM320K-12	1.35	NE561B	5.00	75452CN	.39
LM320K-15	1.35	NE562B	5.00	75453CN	.39
LM320T-5	1.75	NE565H	1.25	75454CN	.39
LM320T-5.2	1.75	NE565N	1.75	75491CN	.79
LM320T-8	1.75	NE566CN	1.25	75492CN	.89
LM320T-12	1.75	NE567H	1.95	75494CN	.89
LM320T-15	1.75	NE567V	1.50	**RCA LINEAR**	
LM320T-18	1.75	LM703CN	.45	CA3013	2.15
LM320T-24	1.75	LM709H	.29	CA3023	2.56
LM323K-5	9.95	LM709N	.29	CA3035	2.48
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LM340K-6	1.95	LM723H	.55	CA3060	3.25
LM340K-8	1.95	LM733N	1.00	CA3080	.85
LM340K-12	1.95	LM739N	1.00	CA3081	2.00
LM340K-15	1.95	LM741CH	.35	CA3082	2.00
LM340K-18	1.95	LM741CN	.35	CA3083	1.60
LM340K-24	1.95	LM741-14N	.39	CA3086	.85
LM340T-5	1.75	LM747H	.79	CA3089	3.75
LM340T-6	1.75	LM747N	.79	CA3091	10.20
LM340T-8	1.75	LM748H	.39	CA3102	2.95
LM340T-12	1.75	LM748N	.39	CA3123	2.15
LM340T-15	1.75	LM1303N	.90	CA3130	1.39
LM340T-18	1.75	LM1304N	1.19	CA3140	1.25
LM340T-24	1.75	LM1305N	1.40	CA3600	1.75
LM350N	1.00	LM1307N	.85	RC4194	5.95
LM351CN	.65	LM1310N	2.95	RC4195	3.25

74LS00 TTL

74LS00	.29			74LS139	1.95
74LS02	.29			74LS151	1.55
74LS03	.29	74LS74	.49	74LS153	1.89
74LS04	.35	74LS75	.69	74LS157	1.55
74LS05	.35	74LS76	.49	74LS162	2.25
74LS08	.29	74LS83	1.75	74LS163	2.25
74LS10	.29	74LS85	2.49	74LS164	1.95
74LS13	.69	74LS86	.49	74LS175	1.95
74LS14	1.75	74LS90	1.25	74LS181	3.69
74LS20	.29	74LS92	1.25	74LS190	2.85
74LS26	.39	74LS93	1.25	74LS191	2.85
74LS27	.39	74LS95	1.95	74LS192	2.85
74LS28	.39	74LS96	1.89	74LS193	2.85
74LS30	.29	74LS107	.59	74LS194	1.89
74LS32	.39	74LS109	.59	74LS195	1.89
74LS40	.39	74LS112	.59	74LS257	1.75
74LS51	.29	74LS132	1.25	74LS260	.55
74LS55	.29	74LS136	.59	74LS279	.79
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Linear	Pin-out & Functional Description	$2.95

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- Displays hour, minute, second, month & day
- Free set of replacement batteries
- Choose LED or LCD styles
- One year factory warranty

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LCD

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FAIRCHILD VIDEO ENTERTAINMENT SYSTEM

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- Freeze Action • Speed Option
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0814 — Spitfire (1 or 2 players)
0815 — Spacewar (2 players)
0818 — Magic Numbers (computer logic)
0819 — Drag strip (1 or 2 players)
0820 — Maze (2 players)
0822 — Baseball (2 players)

DISCRETE LEDS

125'' dia.			.190'' dia.		
XC209	Red	10/$1	XC111	Red	10/$1
XC209	Green	4/$1	XC111	Green	4/$1
XC209	Orange	4/$1	XC111	Yellow	4/$1
XC209	Yellow	4/$1	XC111	Orange	4/$1

.200'' dia			.185'' dia.			.200'' dia.		
XC22	Red	10/$1	XC526	Red	5/$1	XC556	Red	10/$1
XC22	Green	4/$1	XC526	Green	4/$1	XC556	Green	4/$1
XC22	Yellow	4/$1	XC526	Yellow	4/$1	XC556	Yellow	4/$1
XC22	Orange	4/$1	XC526	Orange	4/$1	XC556	Orange	4/$1
SSL-22	RT	4/$1	XC526	Clear	4/$1	XC556	Clear	7/$1

.085'' dia.
MV50 - Red - 6/$1

INFRA-RED LED
¼'' x ¼'' x 1/16''
Flat **5/$1.00**

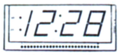
DISPLAY LEDS

DL707 DL33B

TYPE	POLARITY	HT		TYPE	POLARITY	HT	
MAN 1	Common Anode	.270	2.95	MAN 3640	Common Cathode-orange	.300	1.75
MAN 2	5 x 7 Dot Matrix	.300	4.95	MAN 4710	Common Anode-Red	.400	1.95
MAN 3	Common Cathode	.125	3/1.00	DL701	Common Anode-red ±	.300	.99
MAN 4	Common Cathode	.187	1.95	DL704	Common Cathode	.300	.99
MAN 7	Common Anode	.300	1.25	DL707	Common Anode	.300	.99
MAN 7G	Common Anode-green	.300	1.95	MAN 4740	Common Anode-Red	.400	.99
MAN 7Y	Common Anode-yellow	.300	1.95	DL741	Common Anode	.600	1.50
MAN 52	Common Anode-green	.300	.99	DL 747	Common Anode	.600	2.25
MAN 64	Common Anode-red	.400	.99	DL 750	Common Cathode	.600	2.49
MAN 74	Common Cathode	.300	1.50	DL 33B	Common Cathode	.110	.50
MAN 82	Common Anode-yellow	.300	.99	FND70	Common Cathode	.250	.75
MAN 84	Common Cathode-yellow	.300	.99	FND503	Common Cathode	.500	1.00
MAN 3620	Common Anode -orange	.300	1.75	FND507	Common Anode	.500	1.00

FCS 8000A — 3½ Digit — .8'' Display

NEW! 25 Pin Version with colon & am/pm indicator



FRONT VIEW - FSC8000

SPECIAL
$4.95 EA.

- MAXIMUM FORWARD CURRENT — 25 mA.
- Connects almost one for one with 3817, 3817A or D. (3817 available at $5.00 each).
- Typical segment current 8mA except colon, 10 hrs. b & c and 10 min, a & d which are 16 mA.
- Forward voltage drop 1.5 volts.

HP 5082-7300 Series — Multi-Digit

- ⅛'' Ht. • Common Cathode • Dip Package
- 3 to 5 volts @ 5 mils per segment
- 7 segment Monolithic • Red Display

2 Digit	**$ .79**
3 Digit	**.89**
4 Digit	**.99**
5 Digit	**1.19**

IC SOLDERTAIL — LOW PROFILE (TIN) SOCKETS

	1-24	25-49	50-100		1-24	25-49	50-100
8 pin	$.17	.16	.15	24 pin	$.38	.37	.36
14 pin	.20	.19	.18	28 pin	.45	.44	.43
16 pin	.22	.21	.20	36 pin	.60	.59	.58
18 pin	.29	.28	.27	40 pin	.63	.62	.61
22 pin	.37	.36	.35				

SOLDERTAIL STANDARD (TIN)

14 pin	$.27	.25	.24	28 pin	$ .99	.90	.81
16 pin	.30	.27	.25	36 pin	1.39	1.26	1.15
18 pin	.35	.32	.30	40 pin	1.59	1.45	1.30
24 pin	.49	.45	.42				

SOLDERTAIL STANDARD (GOLD)

8 pin	$.30	.27	.24	24 pin	$. 70	.63	.57
14 pin	.35	.32	.29	28 pin	1.10	1.00	.90
16 pin	.38	.35	.32	36 pin	1.75	1.40	1.26
18 pin	.52	.47	.43	40 pin	1.75	1.59	1.45

WIRE WRAP SOCKETS (GOLD) LEVEL #3

10 pin	$.45	.41	.37	24 pin	$1.05	.95	.85
14 pin	.39	.38	.37	28 pin	1.40	1.25	1.10
16 pin	.43	.42	.41	36 pin	1.59	1.45	1.30
18 pin	.75	.68	.62	40 pin	1.75	1.55	1.40

50 PCS. RESISTOR ASSORTMENTS $1.25 PER ASST.

SPECIAL

ASST. 1	5 ea.	10 OHM 27 OHM	12 OHM 33 OHM	15 OHM 39 OHM	18 OHM 47 OHM	22 OHM 56 OHM	1/4 WATT 5% = 50 PCS.
ASST. 2	5 ea.	68 OHM 180 OHM	82 OHM 220 OHM	100 OHM 270 OHM	120 OHM 330 OHM	150 OHM 390 OHM	1/4 WATT 5% = 50 PCS.
ASST. 3	5 ea.	470 OHM 1.2K	560 OHM 1.5K	680 OHM 1.8K	820 OHM 2.2K	1K 2.7K	1/4 WATT 5% = 50 PCS.
ASST. 4	5 ea.	3.3K 8.2K	3.9K 10K	4.7K 12K	5.6K 15K	6.8K 18K	1/4 WATT 5% = 50 PCS.
ASST. 5	5 ea.	22K 56K	27K 68K	33K 82K	39K 100K	47K 120K	1/4 WATT 5% = 50 PCS.
ASST. 6	5 ea.	150K 390K	180K 470K	220K 560K	270K 680K	330K 820K	1/4 WATT 5% = 50 PCS.
ASST. 7	5 ea.	1M 2.7M	1.2M 3.3M	1.5M 3.9M	1.8M 4.7M	2.2M 5.6M	1/4 WATT 5% = 50PCS.

SPECIAL

ASST. 8R Includes Resistor Assortments 1-7 (350 PCS.) **$7.49 ea.**

$5.00 Minimum Order — U.S. Funds Only
California Residents — Add 6% Sales Tax

Spec Sheets - 25¢ — Send 35¢ Stamp for 1977A Catalog
Dealer Information Available

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PHONE ORDERS WELCOME — (415) 592-8097
All Advertised Prices Good Thru September

WIRE WRAP CENTER

HOBBY-WRAP TOOL-BW-630

$34.95
(batteries not included)

- Battery Operated (Size C)
- Weighs ONLY 11 Ounces
- Wraps 30 AWG Wire onto Standard DIP Sockets (.025 inch) Complete with built-in bit and sleeve

WIRE-WRAP KIT — WK-2-W
WRAP • STRIP • UNWRAP

- Tool for 30 AWG Wire
- Roll of 50 Ft. White or Blue 30 AWG Wire
- 50 pcs. each 1'', 2'', 3'' & 4'' lengths — pre-stripped wire.

$11.95

WIRE WRAP TOOL WSU-30
WRAP • STRIP • UNWRAP - $5.95

WIRE WRAP WIRE — 30 AWG

25 ft. min. $1.25 50 ft. $1.95 100 ft. $2.95 1000 ft. $15.00
SPECIFY COLOR — White - Yellow - Red - Green - Blue - Black

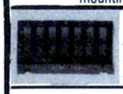
WIRE DISPENSER — WD-30

- 50 ft. roll 30 AWG KYNAR wire wrap wire **$3.45 ea.**
- Cuts wire to desired length
- Strips 1'' of insulation **Specify** — Blue-Yellow-White-Red

HEAT SINKS

205-CB 680-.75A

205-CB	Beryllium Copper w/Black finish for TO-5	**$ .25**
291-.36H	Aluminum for TO-220 Transistors & Regulators	**$ .25**
680-.75A	Black Anodized Aluminum for TO-3	**$1.60**
401-A	Black Anodized Aluminum — predrilled mounting holes for TO-3	**$1.75**



DIP SWITCHES **SPST Slide Action**

#206-4	(8 pin dip)	4 switch unit	**$1.75 ea.**
#206-7	(14 pin dip)	7 switch unit	**$1.95 ea.**
#206-8	(16 pin dip)	8 switch unit	**$2.25 ea.**

TV GAME CHIP SET — $14.95

Includes AY-3-8500-1 chip and 2.010 mhz crystal — if purchased separately would cost $18.95.

ZENERS — DIODES — RECTIFIERS

TYPE	VOLTS	W	PRICE	TYPE	VOLTS	W	PRICE
1N746	3.3	400mm	4/1.00	1N4005	600 PIV	1 AMP	10/1.00
1N751A	5.1	400m	4/1.00	1N4006	800 PIV	1 AMP	10/1.00
1N752	5.6	400m	4/1.00	1N4007	1000 PIV	1 AMP	10/1.00
1N753	6.2	400m	4/1.00	1N3600	50	200m	6/1.00
1N754	6.8	400m	4/1.00	1N4148	75	10m	15/1.00
1N959	8.2	400m	8/1.00	1N4154	35	10m	12/1.00
1N965B	15	400m	4/1.00	1N4305	75	25m	20/1.00
1N5232	5.6	500m	28	1N4734	5.6	1w	28
1N5234	6.2	500m	28	1N4735	6.2	1w	28
1N5235	6.8	500m	28	1N4736	6.8	1w	28
1N5236	7.5	500m	28	1N4738	8.2	1w	28
1N456	25	40m	6/1.00	1N4742	12	1w	28
1N458	150	7m	6/1.00	1N4744	15	1w	28
1N485A	180	10m	6/1.00	1N1183	50 PIV	35 AMP	1.60
1N4001	50 PIV	1 AMP	12/1.00	1N1184	100 PIV	35 AMP	1.70
1N4002	100 PIV	1 AMP	12/1.00	1N1185	150 PIV	35 AMP	1.50
1N4003	200 PIV	1 AMP	12/1.00	1N1186	200 PIV	35 AMP	1.80
1N4004	400 PIV	1 AMP	12/1.00	1N1188	400 PIV	35 AMP	3.00

SCR AND FW BRIDGE RECTIFIERS

C36D	15A @ 400V	SCR	$1.95
C38M	35A @ 200V	SCR	1.95
2N2328	1.6A @ 200V	SCR	.50
MDA 980-1	12A @ 50V	FW BRIDGE REC.	1.95
MDA 980-3	12A @ 200V	FW BRIDGE REC.	1.95

TRANSISTORS

MPS A05	5/$1.00			PN4249	4/$1.00
MPS A06	5/$1.00			PN4250	4/$1.00
2N2219A	3/$1.00	PN3567	3/$1.00	2N4400	4/$1.00
2N2221	4/$1.00	PN3568	4/$1.00	2N4401	4/$1.00
2N2222A	5/$1.00	PN3569	4/$1.00	2N4402	4/$1.00
2N2369	5/$1.00	2N3704	5/$1.00	2N4403	4/$1.00
2N2369A	4/$1.00	2N3705	5/$1.00	2N4409	5/$1.00
2N2484	4/$1.00	2N3706	5/$1.00	2N5086	4/$1.00
2N2906A	4/$1.00	2N3707	5/$1.00	2N5087	4/$1.00
2N2907A	5/$1.00	2N3711	5/$1.00	2N5088	4/$1.00
2N2925	5/$1.00	2N3724	$. 65	2N5089	4/$1.00
2N3053	2/$1.00	2N3725	$1.00	2N5129	5/$1.00
2N3055	$ .89	2N3903	5/$1.00	2N5138	5/$1.00
MJE3055	$1.00	2N3904	4/$1.00	2N5139	5/$1.00
MJE2955	$1.25	2N3905	4/$1.00	2N5209	5/$1.00
2N3392	5/$1.00	2N3906	4/$1.00	2N5951	5/$1.00
2N3398	5/$1.00	2N4013	3/$1.00	C106B1SCR	2/$1.00
		2N4014	3/$1.00	2N5432	$2.00
		2N4123	10/$1.00		

CAPACITOR CORNER

50 VOLT CERAMIC DISC CAPACITORS

	1-9	10-49	50-100		1-9	10-49	50-100
10 pf	.05	.04	.03	.001μF	.05	.04	.035
22 pf	.05	.04	.03	.0047μF	.05	.04	.035
47 pf	.05	.04	.03	.01μF	.05	.04	.035
100 pf	.05	.04	.03	.022μF	.06	.05	.04
220 pf	.05	.04	.03	.047μF	.06	.05	.04
470 pf	.05	.04	.035	.1μF	.12	.09	.075

100 VOLT MYLAR FILM CAPACITORS

.001mf	.12	.10	.07	.022mf	.13	.11	.08
.0022	.12	.10	.07	.047mf	.21	.17	.13
.0047mf	.12	.10	.07	.1mf	.27	.23	.17
.01mf	.12	.10	.07	.22mf	.33	.27	.22

+20% DIPPED TANTALUMS (SOLID) CAPACITORS

.1/35V	.28	.23	.17	1.5/35V	.30	.26	.21
.15/35V	.28	.23	.17	2.2/25V	.31	.27	.22
.22/35V	.28	.23	.17	3.3/25V	.31	.27	.22
.33/35V	.28	.23	.17	4.7/25V	.32	.28	.23
.47/35V	.28	.23	.17	6.8/25V	.36	.31	.25
.68/35V	.28	.23	.17	10/25V	.40	.35	.29
1.0/35V	.28	.23	.17	15/25V	.63	.50	.40

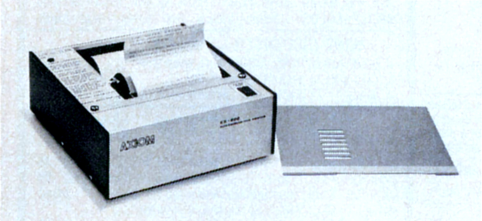
MINIATURE ALUMINUM ELECTROLYTIC CAPACITORS

Axial Lead				Radial Lead			
.47/50V	.15	.13	.10	.47/25V	.15	.13	.10
1.0/50V	.16	.14	.11	.47/50V	.16	.14	.11
3.3/50V	.15	.13	.10	1.0/16V	.15	.13	.10
4.7/25V	.16	.14	.12	1.0/25V	.16	.14	.11
10/25V	.15	.13	.10	1.0/50V	.16	.14	.11
10/50V	.16	.14	.12	4.7/16V	.15	.13	.10
22/25V	.17	.15	.12	4.7/25V	.15	.13	.10
22/50V	.24	.20	.18	4.7/50V	.16	.14	.11
47/25V	.19	.17	.15	10/16V	.14	.12	.09
47/50V	.25	.21	.19	10/25V	.15	.13	.10
100/25V	.24	.20	.18	10/50V	.16	.14	.12
100/50V	.35	.30	.28	47/50V	.24	.21	.19
220/25V	.32	.28	.25	100/16V	.19	.15	.14
220/50V	.45	.41	.38	100/25V	.24	.20	.18
470/25V	.33	.29	.27	100/50V	.35	.30	.28
1000/16V	.55	.50	.45	220/16V	.23	.17	.16
2200/16V	.70	62	.55	470/25V	.31	.28	.26

Circle 305 on inquiry card.

What's New?

New Printer Features Novel Printing Technique



A new 80 column dot matrix printer from Axiom Corporation, 5932 San Fernando Rd, Glendale CA 91202, has been announced which features an operating speed of 160 characters per second. The EX-800, shown at the NCC show in June, features an unusual electrosensitive printing technique: the nonimpact printing is done by passing a high current through fine wires in the print head for about 1 μs to remove the upper layer of aluminum from 5 inch wide electrosensitive paper. This exposes a layer of black ink underneath.

The unit is 9.625 inches (24.45 cm) wide, 3.875 inches (9.84 cm) high and 10.825 inches (27.62 cm) deep. The price is $655, which includes case, power supply, parallel interface and 96 character ASCII character set, programmable character size, built-in self-tester, bell, and infrared low paper indicator.■

Circle 634 on inquiry card.

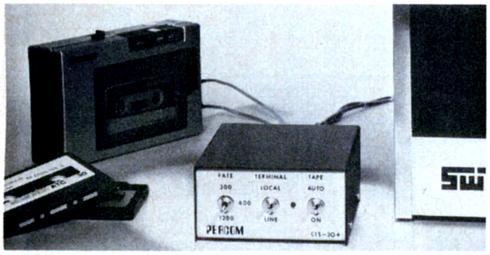
Bell & Howell Offers New Microprocessor Course

Many people have expressed interest in microprocessor correspondence courses. Now, Bell & Howell offers a new source of such courses. Their new microprocessor correspondence course is available for $99. The course materials consist of two study units contained in loose-leaf binders.

Topics covered include an introduction to microprocessors, computer languages, system architecture, IO instructions, flowcharts and so on. For more information, contact Bell & Howell Schools, 209 W Jackson Blvd, Chicago IL 60606.■

Circle 632 on inquiry card.

Cassette Terminal Interface for SwTPC 6800 Operates at 120 bps



PerCom Data Company, 4021 Windsor, Garland TX 75042, has announced a high speed, self-clocking cassette terminal interface for the Southwest Technical Products Corporation 6800 microcomputer.

The CIS-30+, a dual function unit, interfaces cassette data at user selectable rates of 30, 60 or 120 bytes per second, and provides RS-232 interfacing at 300, 600 or 1200 bps.

Cassette data is Kansas City standard biphase encoded.

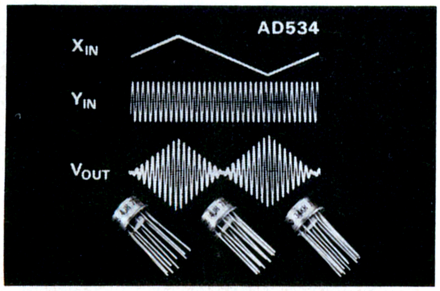
The CIS-30+ user's manual and optional test cassette include PerCom cassette operating software. However, the 6800 resident Motorola MIKBUG is the only software needed for loading at 30 bytes per second. The CIS-30+ will also read unmodified Southwest Technical Products Corporation cassette software.

The CIS-30+ kit is $69.95. The assembled price is $89.95. An instruction manual is included.■

Circle 636 on inquiry card.

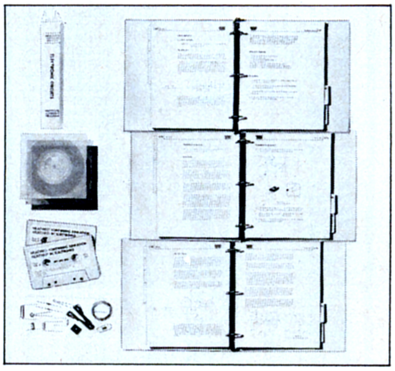
A New Analog Multiplier Series

Analog Devices, Route 1 Industrial Park, POB 280, Norwood MA 02062, has announced a new series of monolithic analog multipliers called the AD534 series. The AD534L, in particular, offers a maximum multiplication error of ±0.25%, said to be the lowest of any integrated circuit multiplier. Small signal bandwidth of these units is 1 MHz, making them ideal for a variety of applications ranging from music synthesis to modulation and demodulation in communications systems. One real advantage for the experimenter is that these multipliers require no external components: simply feed in two analog signals within the input specs and get out their product. Single quantity price for the AD534J is $26.■



Circle 637 on inquiry card.

New Learn-at-Home Electronic Circuits Course from Heath



Heath Company, Benton Harbor MI, has introduced a new learn-at-home electronics course covering basic electronic circuits. The course, EE-3104, is one of four basic electronics courses which use programmed instructions plus audio records. The course comes complete with electronic parts for "hands on" experiments. Other courses in the basic electronics series include AC Electronics, DC Electronics, and Semiconductor Devices. An advanced course in Digital Techniques is also available.

Course EE-3104 covers basic and operational amplifiers, power supplies, oscillators, pulse circuits, modulation and demodulation with emphasis on integrated circuits. An optional final exam can be taken for Continuing Education Units (CEUs), a nationally recognized means of acknowledging participation in noncredit adult education.

Courses are mail-order priced at $39.95. For a free catalog write to Heath Company, Dept 350-18, Benton Harbor MI 49022.■

Circle 635 on inquiry card.

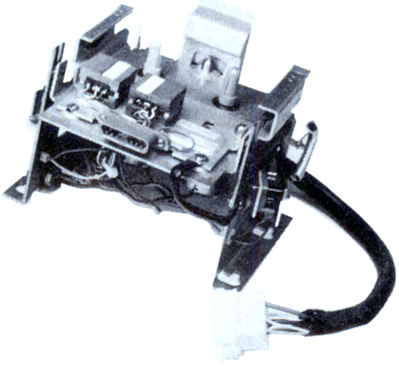
Mini-L Loran-C Receiver Announced

A limited number of circuit boards and a user's guide will be available from R W Burhans, 161 Grosvenor St, Athens OH 45701 or PAIA, 1020 W Wilshire Blvd, Oklahoma City OK 73116, for experimental study of the Loran-C, 100 kHz, navigation system with microprocessor data reduction systems. Mini-L is designed to generate 10 μs interrupt request pulses locked to the Loran-C signals making it a much easier task for microprocessor users to devise their own time measurement software. A 25 page experimenter's manual and two circuit boards (no parts supplied) allow the circuit builder to fabricate an individualized or custom Loran-C antenna preamplifier and radio frequency front-end.

Mini-L contains two user adjustable traps on either side of the Loran-C carrier frequency to help eliminate local area interference, and has a very wide range automatic gain control (AGC) level for hard limiting on signals received. The level control can be arranged to

FIRE-SMOKE-INTRUDER ALARM

12 volt DC operation, large 5 inch bell, one unit, all the works under the bell. Nice for camper, boat, homes. $25



VIATRON CASSETTE DECKS

The computer cassette deck alone $35 Set of 2 boards read/write amp & serve control boards for this deck $40.00

PORTABLE FIRE ALARM

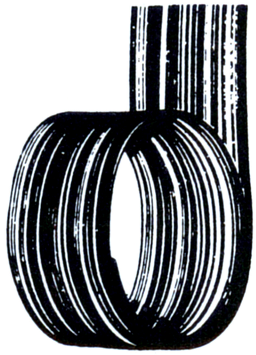
Operates on 3 internal AA cells (not furnished) On temp rise of approx 150 Sonalert type alarm sounds off. Push to test switch makes nice sounding code practice oscillator $6.00

SPECTRA FLAT TWIST

50 conductor, 28 gauge, 7 strands/conductor made by Spectra. Two conductors are paired & twisted and the flat ribbon made up of 25 pairs to give total of 50 conductor. May be peeled off in pairs if desired. Made twisted to cut down on "cross talk." Ideal for sandwiching PC boards allowing flexibility and working on both sides of the boards. Cost originally $13.00/ft

SP-324-A $1.00/ft. 10 ft/$9.00

SP-234-A	$1.00 ft	50 cond.	10 ft/$9.00
SP-234-B	.90 ft	32 cond.	10 ft/$8.00



WIRE WRAP WIRE

TEFZEL blue #30 Reg. price $13.28/100 ft. Our price 100 ft $2.00; 500 ft $7.50.

MULTI COLORED SPECTRA WIRE

	Footage	10′	50′	100′
8 Cond.	#24	$2.50	9.00	15.00
12 "	22	3.00	11.00	18.00
14 "	22	3.50	13.00	21.00
24 "	#24	5.00	20.00	30.00
29 "	22	7.50	28.00	45.00

Great savings as these are about 1/4 book prices. All fresh & new.

TOUCHTONE ENCODER CHIP

Compatible with Bell system, no crystal required. Ideal for repeaters & w/specs. $6.00

CHARACTER GENERATOR CHIP

Memory is 512x5 produces 64 five by seven ASCII characters. New material w/data $6.00

Meshna

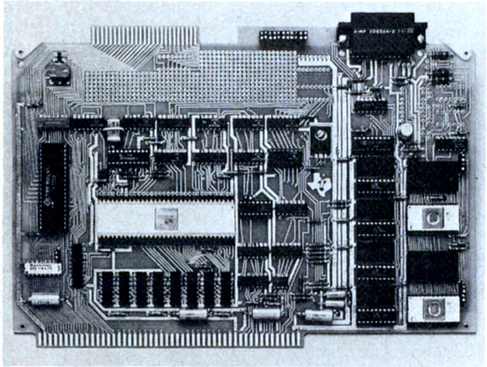
Please add shipping cost on above. Minimum order $10
FREE CATALOG SP-9 NOW READY
P.O. Box 62, E. Lynn, Massachusetts 01904

Circle 306 on inquiry card.

operate either manually or under software control from an external digital to analog converter. The wideband antenna preamplifier may also be used with the Mini-O system as described in March 1977 BYTE. An improved Mini-O circuit board is being developed.■

Circle 638 on inquiry card.

A New Series of 16 Bit Microprocessors from Texas Instruments



Texas Instruments has announced a new series of 16 bit single board microcomputer modules based on the 9900 chip which feature upward and downward software compatibility with the rest of the 9900 series. The TM990/100M is the first module to be made available in the new TM990 series. It features 1 K by 16 bits of erasable read only memory expandable to 4 K by 16 bits (the memory will include a self-contained software monitor called TIBUG), plus a 256 x 16 bit volatile user programmable memory expandable to 512 by 16 bits on the board.

Sixteen lines of programmable parallel IO and a selection of either a current loop or RS-232 terminal interface are available. In addition, the TM990/100M offers two programmable interval timers, 15 external hardware interrupts and a blank board area with extra sockets for user prototyping, etc. The TM990/100M sells for $450, assembled, in single quantities.

This will provide an excellent starting point for the experimenter desiring a 16 bit minicomputer-like processor which features hardware (integer) multiply and divide, real shift instructions and a general register architecture.

For further information, contact Texas Instruments Inc, Inquiry Fulfillment, POB 1443, M/S 653 (Attn: TM990), Houston TX 77001.■

Circle 639 on inquiry card.

A New Smart Terminal from Economy Terminals

Economy Terminals has announced their Model ET1 microprocessor-based video terminal for the experimenter market priced at $895 each. Hardware features include:

- 24 by 80 display of a 64 character ASCII subset (but a full 96 character set is transmitted)
- 12 inch (30.5 cm) industrial video monitor
- RS-232 and 20 mA current loop interface
- 16 switchable data transfer rates
- Switch selectable odd or even parity with one or two stop bits
- 63 key keyboard with all functions identified on key caps

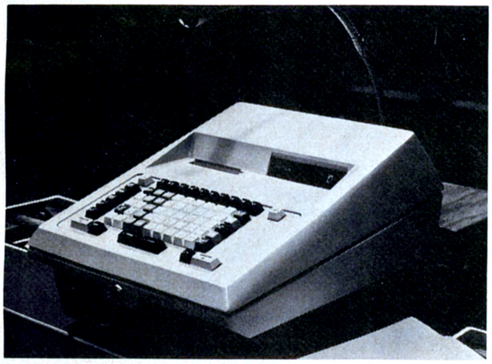
Software features include:

- Page or scrolling mode of operation
- XY placement of cursor either from keyboard or remotely
- Automatic repeat of any key after a 0.3 second delay

For further information, write Economy Terminals, POB 12261, Minneapolis MN 55412.■

Circle 640 on inquiry card.

Get Some Pizza Mind



"Big Stan," a new version of the MARK III line of electronic point-of-sale systems by FasFax Corporation, is currently in trial with prospects in the pizza and taco segments of the fast food industry. The new system automatically prices add-on ingredients to speed counter service and eliminate losses caused by incorrect pricing procedures. It uses its microcomputer intelligence to increase the productivity of food vendors. [*Oh! The power of user oriented firmware* . . . CH] Big Stan is programmed to allow for many basic carriers, such as different sizes of pizza shells and a wide variety of ingredients. The ingredients can be assigned to as many as 15 different price classes, thus assuring accuracy regardless of the way clerks enter the order. The unit maintains a complete record of all transactions, labor hours and inventory changes; this information is used to automatically compile management reports. For more information, contact FasFax Corporation at Ledge St, POB H, Nashua NH 03060.■

Circle 641 on inquiry card.

Small Business Software from Synchro-Sound

Synchro-Sound, 193-25 Jamaica Av, Hollis NY 11423, has announced an accounts receivable system for the small businessman. The system is expressly designed to be run on an 8080 microcomputer using an Altair floppy disk with Altair BASIC, video terminal and printer. Features include: adding new customer accounts, deleting dormant accounts, transaction processing and report generation. The monthly statements include both current and aged balances. Other reports generated are aged accounts receivable and delinquency notices.

The system is said to require little operator training. All communication is in interactive mode. Operator errors are easily corrected, and accidental data base deletions are prevented by requiring additional confirmation.

This system may be modified to include special installation dependent functions. All major programs are written in high level language to facilitate program additions and alterations. This program module is designed to serve as the basis for a complete accounting package. Provisions are included for linking billing, inventory control and general ledger modules. The latter will be available in the near future.■

Circle 643 on inquiry card.

A Most Useful Catalog

Here at last is a source for all those hard-to-get accessories and supplies for mini and microcomputers: Minicomputer Accessories' new 1977 catalog. Small systems enthusiasts will enjoy paging through this compendium which features such things as binders for computer printouts, flowchart design templates, printer paper, cassette storage boxes, cordless paper tape winders, paper tape splicers and trays, myriads of special interconnection cables, extender boards, cable bridge systems for covering floor runs of computer cables, storage cabinets, and so on. The catalog is free for the asking from Minicomputer Accessories, 1015 Corporation Way, POB 10056, Palo Alto CA 94303.■

Circle 642 on inquiry card.

cybercom BOARDS

MB-1 MK-8 Computer RAM, (not S-100), 4KX8, uses 2102 type RAMs, PCBD only $22

MB-3 1702A EROM Board, 4KX8, S-100, switchable address and wait cycles, kit less PROMS $65

MB-4 Basic 4KX8 ram, uses 2102 type rams, may be expanded to 8KX8 with piggybacking, S-100 buss. PC board $30

MB-6 Basic 8KX8 ram uses 2102 type rams, memory protect in 256 to 8K switchable S-100 buss. PCBD $35

MB-8 2708 EROM board, S-100, 8KX8 or 16KX8 kit without PROMS $85

IO-2 S-100, 8 bit parallel I/Oport, ⅔ of board is for kludging. Kit...... $55 PCBD $30

VB-1 64X 16 video board, upper lower case Greek, composite and parallel video with software, S-100. Kit...... $189.00 PCBD $35

SP-1 Music synthesizer board, S-100, computer controller wave forms, 9 octaves, 1V rms ½% distortion, includes software kit $250

Altair Compatible Mother Board, 11 x 11½ x ⅛". Board only... $45 With 15 connectors $105

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Solid state music Cybercom boards are high quality glass board with gold finger contacts. All boards are check for shorts. Kits only have solder mask. 90 day guarantee on Cybercom kits.

Waneco Boards

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Mother Board 12 slot, terminated, S-100, board only $40

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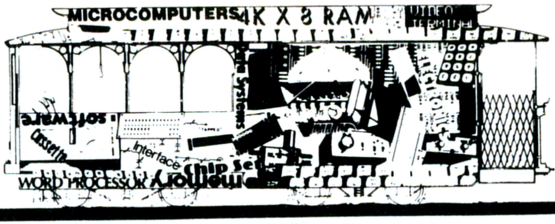

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ASTROLOGY: I am interested in getting in touch with anyone doing astrological chart computation and progression on minicomputer systems. P Pierce, Bone and Joint Surgery Association, Data Processing Dept, 2704 Marshall Ct, Madison WI 53705.

HELP: I need schematics and electrical specs for a Friden Selectadata paper tape reader, Model STR. Also need schematics and specs and a "Technical Manual" for a Friden Programmatic Flexowriter, Model SPD. I will buy the manuals or pay for copies. John Kane, USS Enterprise, AIMD IM3 WC630, FPO San Francisco CA 96601.

WANTED: January, February, March, April, May and June 1976 BYTEs. Will pay any reasonable price. Send offers and lists to Reuben Plant, 43 Avista Cir, St Augustine FL 32084.

FOR SALE: One ASR-33 friction feed Teletype complete with reader, punch, and stand, $700. One ASR-33 sprocket feed Teletype with stand and punch, but no reader, $400. One ASR-33 sprocket feed Teletype with stand, no reader or punch, $350. Daniel Skret, 2485 Painted Rock Dr, Santa Clara CA 95051, (408) 296-6783 or (408) 246-8686.

FOR SALE: Video data terminal, RCA Model 70/752, 12 inch screen, 20 lines by 54 Characters. Full editing capability and cursor control, data insert. Output: RS232, 1,200 baud, ASCII. Self-contained power supply, timing clock, and two IO boards. ASCII keyboard included, also schematics, specs, etc, $600 or offer. Dick Blayney, 11241 Laurianne Ln, Garden Grove CA 92641, after 5 PM (714) 539-9175.

FOR SALE: MOD 80-1, fully populated, untested; MOD 8-2, tested; two each MOD 8-4 and MOD 8-5, unpopulated. $150 for set. RM Terminal as advertised by Micro-Mart, less power supply and printer, $80. Ron Burris, 701 E Pine #143, Lompoc CA 93436.

FOR SALE: MOS Technology, KIM 1, $175. Perfect condition. Presently running with ASR 33 and cassette tape deck. Complete with all MOS manuals and many programs including Lunar Landing, a text assembler, Hi-Lo and computer roulette games, and a Morse code teaching program. Will sell ASR 33 for $700. I would like to buy or trade above for a DEC PDP-8. Andy Ring, 49 Main St, Yarmouth ME 04096, (207) 846-5651 or (207) 846-5800 after 5:00.

CIPHERING: Privacy, cryptography, security. Tutorial book, 6603 computer compiled ciphering algorithms, demonstration cipher systems, $13.25. Clay Pierce, POB 4747, Saticoy CA 93003.

FOR SALE: I have several commented listings of SwTPC's MP-E resident assembler for the M6800. Full 132 column paper, $20 each. George Cruz, 938 Enterprise Av, Inglewood CA 90302.

Readers who have equipment, software or other items to buy, sell or swap should send in a clearly typed notice to that effect. To be considered for publication, an advertisement should be clearly noncommercial, typed double spaced on plain white paper, and include complete name and address information. These notices are free of charge and will be printed one time only on a space available basis. Insertions should be limited to 100 words or less. Notices can be accepted from individuals or bona fide computer users clubs only. We can engage in no correspondence on these and your confirmation of placement is appearance in an issue of BYTE.

Please note that it may take three or four months for an ad to appear in the magazine.■

FOR SALE: NCR data based cassette tapes with clear leaders (have been used) but bulk erased, $4 each or $3.50 each per dozen. Price includes shipping; supply limited; first come first served. Send cashier's check or money order to Lou Oddo, 2200 Forsyth Rd, Box 28, Orlando FL 32807.

FOR SALE: PolyMorphic, POLY 88 computer, $480. Seals 8KSC-Z, 8 K high speed memory board, $250. Several IMSAI boards, Tarbell, and PolyMorphic boards. Call (213) 477-8478 for details, or send SASE to Roger Lewis, 1477 Barrington #17, Los Angeles CA 90025.

WANTED: I am a high school student in need of an inexpensive TTY. I wish to use it as an output device for my COSMAC 1802 system and would appreciate any information that would lead to the purchase of such a device. If you can help with this or other devices, please contact Darcy Roberts, 660 Laurier Blvd, Brockville, Ontario, K6V 5X8, CANADA.

WANTED: Economical IBM Selectric or equivalent quality terminal for high quality hard copy. Must have upper and lower case character set, but can be any standard code and keyboard need not be operative. Steve Goldband, 160 Auburn Av, Buffalo NY 14213.

SUMMER 1978: German student (microtechniques, 3rd half-year now) searches opportunity to get some practical experience in small systems and technical English in the USA. Goetz Kluge, Loreleystrasse 93, D6230 Frankfurt 80, W GERMANY.

FOR SALE: IMSAI 8080, 22 slot mother board with 9 expms; 8 K Vector Graphics programmable memory, professionally assembled, never been used, guaranteed. $999. Please call (415) 548-2024, after 7 PM, weekdays only. Gary Melton, 1707B Lincoln St, Berkeley CA 94703.

FOR SALE: 8 K 8080a System, Intel bus 8080a CPU with 6 IO ports, sockets for three more (add one chip), board set up for up to 3 K PROM, 2 to 4 K 450 ns static low power programmable memory TVT III with 2 K programmable memory, UART board, cursor control board, HITS cassette interface (space for bootstrap PROM), Hall effect ASCII keyboard, 5 A power supply, case and connectors for 64 K, full documentation, new, not used, backplane unassembled, first $975. D. Krivoshik, 18 Newcomb Pl, Elizabeth NJ 07202.

FOR SALE: Sphere 320 System (and more!). Includes CPU board, keyboard, serial interface board (SIM), power supply, 4 K memory board expandable to 16 K (in addition to 4 K of programmable memory on the CPU board), and a video monitor with interface board, all enclosed in an attractive case. Included with this system is a 16 channel 8 bit analog to digital converter for work with analog signal monitoring. Assembly required on the SIM and memory board, but the basic system is up and running on a resident text editor and debugging system in 1 K of PROM. The first check for $1500 will get this excellent high quality system. Brent Bardsley, 1366 Blaine Av, Salt Lake City UT 84105.

FOR SALE: Three MITS 4 K static programmable memory boards. Assembled, tested and burned in, absolutely new condition. $185 each, $360 for two, $525 for three. I will pay shipping. Chris Pettus, POB 611, Malibu CA 90265.

FOR SALE: Intersil Intercept Jr single board computer with programmable memory, ROM monitor, keyboard and LED display, with plug-in serial 20 mA Teletype or RS-232C interface and plug-in 2 channel output interface. New price $360, will accept highest offer over $225. Peter Stark, POB 209, Mt Kisco NY 10549, (914) 241-1027.

FOR SALE: CT-1024 TV terminal completely assembled in a beautiful wood enclosure. Ready to attach to any TV, includes: Pixiverter, ASCII keyboard, all cursor and erase functions as push-buttons, computer cursor control card, serial interface as RS232C. Plus (unimplemented) scroll mod and 64 character mod board. Only $325 postpaid. B J Yarkon, 1457 Broadway, Room 305, New York NY 10036.

WANTED: Software. Resident assembler and Tiny BASIC for my Motorola 6800 (20 K) system. I will pay for cost of duplication and mailing. If there is somebody out there who is interested in exchanging programs and hardware information for the Motorola 6800, please write. R Veening, Paul Krugerlaan 113, Den Haag HOLLAND.

FOR SALE: Data Reference Card for RCA 1802 microprocessor. Send $1 plus self-addressed stamped envelope to R W Moell, 5505 Daywood Ct, Raleigh NC 27609.

FOR SALE: E and L instruments MMD-1 8080a based microcomputer complete with keyboard, 256 bytes programmable memory, 256 bytes of PROM programmed for keyboard entry and execution of programs, power supply, inferfacing and breadboarding socket, case, and 40 pin edge connector for expansion. Includes modular, self-taught microprocessor course. Assembled, tested, excellent condition, $350. Edward D Paradise, 33 Viola Ln, New Britian CT 06053, (203) 223-2883.

IBM 1620: Being modified; additional core, peripherals are to be attached; tape, disk, cassettes, printer are to be attached; any comments, suggestions as to probable problems etc, will be appreciated. Please contact T K Maki, 102 Minott Rd, Westminster MA 01473.

GAMERS: I have compiled a book of BASIC games. Most are new games. If you wish to have a copy, send $10 in the form of a check or money order to Mike Brothers, 4100 Saratoga Dr, Bloomington IN 47401. Indiana residents add $.40 for sales tax.

FOR SALE: New 102 switch keyboard printed circuit board double sided, plated through holes, 16¼ by 7 inch board. ASCII output or can be changed with 1702A PROM for any 7 bit code. All schematics, parts list, modifications (only five left) $6. Also Motorola crystal oscillator K1091A (20 MHz $10 new), (4 MHz $6 used) 14 pin dip. 4 MHz perfect for OSI video board optional oscillator. Also have miscellaneous parts: bridge rectifiers, filter caps, 6501, 8008, Mark-8 boards, C mod-8 boards, Monitor-8 ROM, 8008 manuals, books, etc. Send SASE for complete list to Ron Angstadt, RD#3, Box 281, Kutztown PA 19530.

FOR SALE: 18 digital cassette tapes and cases by Wang Labs Inc. Like new $2 each. 30 Shugart full size floppies, most barely used $4 each. Harry Morrow, 437 Barton Run Blvd, Marlton NJ 08053. Call daytime (215) 586-3600.

FOR SALE: Two GSI 110 floppy disk drives, single or dual density, soft or hard sector drives. The electronics boards are fully optioned, including data separator, a complete set of documentation and all connectors and cables. $350 each or $650 for the pair. Jim Baumgardt, 6343 Lincoln Av, Apt F-2, Buena Park CA, (714) 826-7056.

FOR SALE: Selectric IO keyboard printer service manual, clean and barely used, $20 or early issues of BYTE in trade. Michael Craig, POB 895, West Acton MA 01720.

FOR SALE: Teletype ASR-33 in very good condition, with manuals, $600. MITS 88-ACR audio cassette interface, assembled and working, $120. I need more memory and an IO board (RS-232) for S-100 bus and would consider a trade-in on the above items. Donald Bailey, 19 Shaker Rd, Concord NH 03301.

CHESS: BYTE readers interested in exchanging information about computer chess, finding postal opponents for their computer chess programs or organizing a tournament are invited to write me. R M Hord, 3407 N Third St, Arlington VA 22201.

FOR SALE: Complete set of BYTEs, all issues from first thru April 1977. Best offer. Jim McCord, 330 Vereda Leyenda, Goleta CA 93017.

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BOMB
BYTE's Ongoing Monitor Box

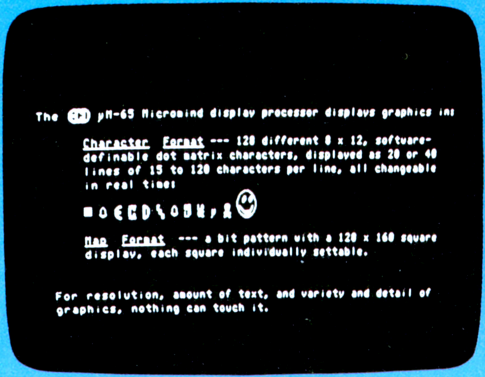
BOMB's Double Header. . .

As noted last month, due to the delay in mailing the May 1977 issue caused by a printing plant strike, the analysis of May's reader reactions to articles was delayed by one month. This month, then, the analysis covers the May and June issues.

On BOMB Card, Article No.	ARTICLE	PAGE
1	**Taylor: SCORTOS: Implementation of a Music Language**	12
2	**Atkins: A New Dress for KIM**	26
3	**Ciarcia: Control the World! (Or at Least a Few Analog Points)**	30
4	**Emmerichs: Expanding the Tiny Assembler**	44
5	**Rampil: One-Sided View of Wire Wrap Sockets**	54
6	**Chamberlin: Techniques for Computer Performance of Music**	62
7	**Sierad: Tune in with Some Chips**	84
8	**Hauck-Nash: The Noval 760**	102
9	**Helmers: Notes on Interfacing Player Pianos**	112
10	**Morgan: Notes on Anatomy: The Piano's Reproductive System**	122
11	**Wimble: An APL Interpreter for Microcomputers: Part 2**	126
12	**Jacoby: Walsh Functions: A Digital Fourier Series**	190

For May, the winner was Sheldon Linker's "What's in a Floating Point Package?" Author Linker thus receives the $100 first prize bonus, while second place (and a $50 bonus) went to Jack Emmerichs' article, "Implementing the Tiny Assembler." The May issue statistics found the winner at 1.1 standard deviations away from the mean of all article votes, with the standard deviation coming in at 15% of the mean. May articles had fairly uniform reactions from readers as measured by the relatively small deviation in votes for the various articles.

In contrast, the June voting was characterized by an overwhelming "spike" in the response, with the winning entry Ralph Hollis' "Newt: A Mobile Cognitive Robot." He won the voting (and the $100 prize) easily with a positive margin of 2.1 standard deviations away from the mean. Second place at 0.6 standard deviations was Dan Fylstra's article on "Interfacing the IBM Selectric Keyboard Printer." Reflecting the "spike" in favor of Newt, the standard deviation of this group of votes was 23% of the mean.■



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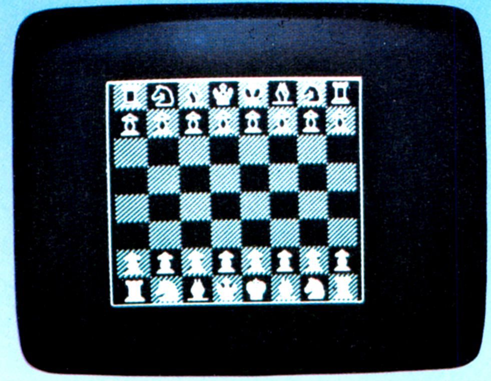

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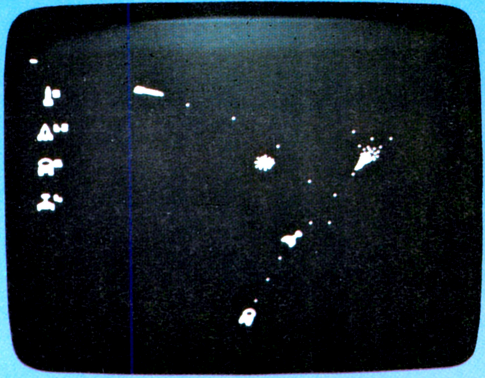

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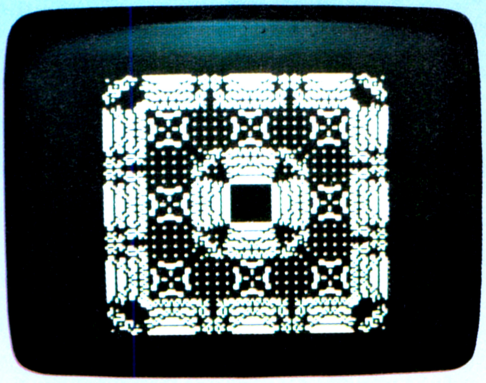

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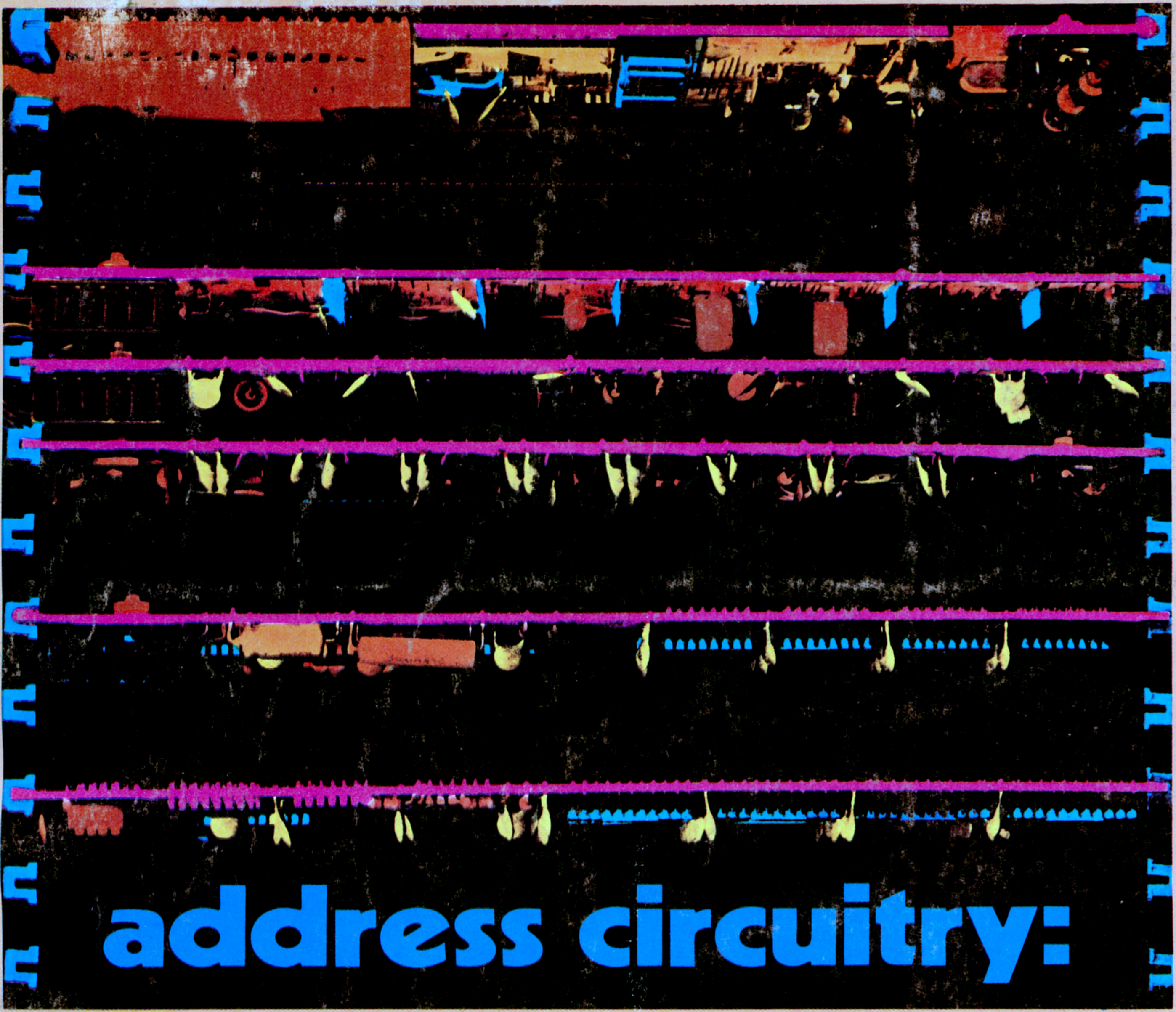

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